ENGINEERING:

An Illustrated Weekly Journal.

EDITED BY WILLIAM H. MAW AND B. ALFRED RAWORTH.

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Page 114, July 18.

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See page 17, July 18. 7262

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See page 15, July 18. 7454

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See Advertisement page 101.

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See Advertisement page 28. 7268

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See's Patent Hydro-Pneumatic **Ash Ejector.**
Great saving of labour. No noise. No dust. No dirt. Ashes discharged 20ft. clear of vessel.—Apply, F. J. TREWENT & PROCTOR, LTD., Naval Architects and Surveyors, 43, Billiter Bldgs., Billiter St., London, E.C. Od 4586

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See Advertisement page 29, July 18. 3409

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See half-page Advertisement page 105, July 11.

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PATENTS AND DESIGNS ACT, 1907.

Notice is Hereby Given that

ALBERT DELAS, of 18, Rue de Liege, Paris (Seine), France, SEEKS LEAVE to AMEND the Specification left in connection with his Application for Letters Patent No. 123059 (21313 of 1918) for "Improvements in or relating to Steam Injectors." Particulars of the proposed Amendment were set forth in the *Illustrated Official Journal (Patents)* issued on the 16th July, 1919. Any person or persons may give notice of opposition to the Amendment by leaving Patents Form No. 18 at the Patent Office, 25, Southampton Buildings, London, W.C.2, within one calendar month from the date of the said Journal. X 376

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PETER MACNAUGHTON, S.S.C., Clerk.

George Heriot's Trust,
10, York Place, Edinburgh.
16th July, 1919. X 388

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TENDERS.

G. R.

BY DIRECTION OF THE DISPOSAL BOARD, MINISTRY OF MUNITIONS.

NOTE.—For detailed list of all surplus Government Property for sale, apply at the nearest bookstall or to the Director of Publicity, Ministry of Munitions, Whitehall Place, S.W. 1, for *Surplus*, price 3d.

For Sale, by Public Tender,

BRICK and PIPE-MAKING MACHINERY, as follows:—

One Plaster Brick-making Machine, 22 in. diam., in pug barrel, capable of producing 12,000 bricks per day of 10 hours, fitted with pair of Horizontal Crushing Rollers, 20 in. diam. by 24 in. wide on face. Driven by strong Spur Gearing, with F. & I. Palleys and Friction Clutch as a preventative against damage should machines become clogged. Complete One Plain Brick Die for ordinary bricks, and Improved Cutting Table.

HAND POWER PIPE MAKING MACHINE.—Barrel 24 in. long by 10 in. diam. to suit Plunger operated by Rack and Pinion, 4 in. face and Double purchase Spur Gearing, 3 in. face and Hand Wheels. Table 23 in. diam., complete with Two Sockotting Dies and Apparatus for cutting spigots and pipes to the length required. Above lying at Accrington.

LOCOMOTIVES (Narrow Gauge).—By Manning, Wardle & Co., Two; W. G. Bagnall & Co., Three. Type: saddle and side tank, gauge 1 ft. 6 in., working pressures 120 to 140 lb. per sq. in., wheel bases 3 ft. 6 in. and 3 ft. 3 in. All these are in running order. A number of spares are available.

HYDRAULIC GANTRY CRANES (TWO).—Makers Tannett Walker & Co., Leeds; capacity 6 tons, working pressure 750 lb. per sq. in., radius approximate 30 ft., lift 18 ft., height overall 48 ft., gauge rails 13 ft. 4 in., wheel base 13 ft. 3 in. Ample room in gantry to take Standard Gauge Wagons. Above lying at Royal Ordnance Factory, Woolwich.

Tenders must be submitted not later than 10 a.m., July 31st. Further particulars, Tender Forms and permits to view can be obtained on application to the CONTROLLER, Plant and Machinery Section, Charing Cross Embankment Buildings, London, W.C. X 231

G. R.

BY DIRECTION OF THE DISPOSAL BOARD.

NOTE.—For Detailed List of all Surplus Government Property for Sale, apply at the nearest Bookstall or to the Director of Publicity, Ministry of Munitions, *for Surplus*, price 3d.

The Minister of Munitions,

has FOR SALE:—

1990 MILD STEEL TUBES, 3 ft. 2 in. long by 1 in. internal dia. by 1⅛ in. external dia., weighing about 5½ lb. each, in good condition and unworked.

100 MILD STEEL TUBES, same as above with one end of Tube boxed for 4 in. to fit 1½ in. by ⅜ in. bar, in good condition and otherwise unworked.

TENDERS ARE INVITED.

Tender Forms can be obtained at ROOM 382, HOTEL METROPOLE, London, S.W.
Ref. DD1/1169. X 421

CITY OF BRADFORD.

The Bradford Corporation invite

Tenders for the Supply, and

ERECTION of the following:—

CONTRACT "R.115."—THREE WATER-TUBE BOILERS, SUPERHEATERS, STOKERS, &c., and

CONTRACT "R.116."—NATURAL DRAUGHT CHIMNEY-TYPE COOLING TOWER.

Copies of the Specifications, General Conditions of Contract, Forms of Tender, &c., may be obtained from Mr. THOMAS ROLES, City Electrical Engineer and Manager, Electricity Offices, Town Hall, Bradford, on payment of the sum of One Guinea for the Specification, &c., for each Contract. Additional copies of the Specifications may be obtained on payment of the sum of half-a-guinea per copy. The sums paid will only be refunded upon receipt of a *bona fide* Tender, with the return of all the documents in good condition, and after the Tenders have been adjudicated upon.

Sealed Tenders, on the Forms provided, must be sent, fully filled in, to me not later than 10 a.m., on Friday, the 15th August, 1919, endorsed, "Tender for Electricity Works, Contract 'R.115' or 'R.116,'" as the case may be.

The Contracts will be let, subject to the Fair Contracts Clauses of the Corporation, which may be seen at the Town Clerk's Office, and which the accepted Contractors will be required to sign.

The lowest or any Tender will not necessarily be accepted.

FREDERICK STEVENS,
Town Hall, Bradford, Town Clerk.
22nd July, 1919. X 413

G. R.

BY DIRECTION OF THE DISPOSAL BOARD, MINISTRY OF MUNITIONS.

NOTE.—For Detailed List of all Surplus Government Property for Sale, apply at the nearest Bookstall, or to the Director of Publicity, Ministry of Munitions, Whitehall Place, S.W.1, for *Surplus*, price 3d.

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BY TENDER.

Consisting of the following:—

Orange Chipping and Marmalade-making Machines, Potato and Milling Machines, Water Tanks, Dipping Tanks, Oil and Petrol Tanks, Fans, belt and electrical driven, up to 75,000 cubic ft. per minute; Screw Jacks, up to 16 tons; Grinding Roller Mills and parts. Electric Cranes as follows:—Overhead, 2-ton girders, 42 ft. 8 in.; ditto 5 tons. Friction Hoist, drum 15 in. by 4½ in.; Oil Separators, Thermometers and Pyrometers, Smiths' Tools and Requisites, consisting of Forges, Anvils, Brazing Hearths, Fire Extinguishers, Fire Hose Car, Pumps, &c., Stoves, tinman's, with flexible tubing; Drying Stoves, Heating Stoves, Enamelling Stoves; Muffles, gas heated; Furnaces for Annealing, gas and electric heated; Cisterns, open and closed types, galvanised suitable for hot water; Photo Printing Machines, Drying Kilns, Sand Blast Apparatus, Spraying Machines.

Dust Exhausting Plant, Paint and Varnish Sprayers, Gas Meters, Semi-rotary Pumps, and other Engineering Accessories including Piping, &c.

State items for which particulars are required. Particulars of above, together with Tender Forms, can be obtained on application to the CONTROLLER, D.B. 1E, Charing Cross Embankment Buildings, London, W.C. 2. X 106

G. R.

BY DIRECTION OF THE DISPOSAL BOARD, MINISTRY OF MUNITIONS.

NOTE.—For Detailed List of all Surplus Government Property for Sale apply at the nearest Bookstall or to the Director of Publicity, Ministry of Munitions, Whitehall Place, S.W., for *Surplus*, price 3d.

Machinery, Shafting, Etc.—

FOR SALE, BY PUBLIC TENDER, Machinery, Shafting, etc., at the National Tin Package Repair Factory, Mackean Street, Paisley, consisting of:—

Screw Presses; Bending Machine for heavy work; Rotary Gas Compressor 300 cu. ft. per hour at 3 lbs.; Bliss Toggle Drawing Press about 9000 lb. weight; Grooving Press suitable for drums and cylinder work; Power Press 3 in. stroke, by Taylor & Challen; Foot Power Guillotine to cut up to 21 gauge; Bench Grinding Head; Swaging Machine 36 in. gap; Power Shearing Machine, cut 21 gauge; Power Punching Presses; Sensitive Drilling Machine; Small Soldering Stoves; Dynamo 9.4 HP. shunt wound 200 volts, ventilated type with S. regulator; Electric Cable and Conduits; Shafting, Pulleys, Brackets, etc.; No. 3 Wells Oil Filter; Counter Weighing Machine 2 lbs.

Above to be sold in large or small lots.

Tenders must be submitted by 10 a.m., August 14th.

Tender Forms and permits to View can be had on application to the CONTROLLER, Machinery and Plant (Demobilisation), Charing Cross Embankment Buildings, W.C. 2. X 364

The Commissioners of

His Majesty's Works, etc., are PREPARED to RECEIVE TENDERS, before 11 a.m., on Wednesday, the 6th August, 1919, addressed to THE SECRETARY, H.M. Office of Works, etc., Storey's Gate, Westminster, London, S.W. 1, for the SUPPLY of CONDUIT TUBES AND FITTINGS (during a period of 6 or 12 months from date of acceptance of tender).

Forms of Tender, etc., may be obtained on application to the CONTROLLER OF SUPPLIES, H.M. Office of Works, etc., King Charles Street, Westminster, London, S.W. 1. X 449

BATTERSEA BOROUGH COUNCIL.

MACHINERY FOR CLEANING AND CUTTING FOR RE-USE OF OLD WOOD PAVING BLOCKS.

The Council Invite alternative

Tenders for the Supply of

MACHINERY for:—

(i) Cleaning Wood Blocks.
(ii) Cutting Wood Blocks.
(iii) Cleaning and Cutting Wood Blocks.

Further particulars may be obtained at the Town Hall.

Tenders (sealed and endorsed) containing full particulars as to the capacity, etc., of the machinery must reach me by Noon, on Thursday, the 31st July.

W. MARCUS WILKINS,
Town Clerk.

Town Hall,
Battersea, S.W.
July, 1919. X 408

THE GREAT INDIAN PENINSULA RAILWAY COMPANY.

The Directors are prepared to receive

Tenders for the Supply of the

following STORES, namely:—

	Specification Fee.
Sieves, Riddles, etc.	5/-
Carriage Underframes with 4-wheel Bogies and Carriage Underframes with 6-wheel Bogies	£1
Laminated Springs, etc.	10/-
India Rubber Sheets, etc.	10/-
Mild Steel Plates and Sheets for miscellaneous purposes.	£1
Mild Steel Bars, Sections, etc., for miscellaneous purposes.	£1
Platelayers' Tools.	£1

Specifications and Forms of Tender may be obtained at this office on payment of the fee for the Specification, which payment will not be returned.

Tenders must be delivered in separate envelopes, sealed and addressed to the undersigned, marked "Tender for Sieves, Riddles, etc.," or as the case may be, not later than Eleven o'clock a.m. on Wednesday, the 6th August, 1919.

The Directors do not bind themselves to accept the lowest or any Tender.

R. H. WALPOLE,
Secretary.

Company's Offices,
48, Copthall Avenue,
London, E.C.
23rd July, 1919. X 424

G. R.

BY DIRECTION OF THE DISPOSAL BOARD, MINISTRY OF MUNITIONS.

NOTE.—For detailed list of all Surplus Government Property for Sale, apply at the nearest Bookstall, or to the Director of Publicity, Ministry of Munitions, Whitehall Place, S.W., for *Surplus*, price 3d.

Sale by Public Tender of

MACHINES and PLANT, lying at Royal Aircraft Establishment, South Farnborough.

3	No. 53 Cleveland National Acme Autos., 4 spindle.					
1	No. 52	"	"	"	4	"
2	No. 55	"	"	"	4	"
1	No. 56	"	"	"	4	"
1	Cleveland National Acme Auto., Single Spindle by ½ in.					
1	Cleveland National Acme Auto., Single Spindle by ½ in.					
1	Alexander, B'ham, Auto m/c, Single Spindle by ½ in.					
1	No. 0. B. & S. Auto., Single Spindle by ½ in.					
1	No. 3.	"	"	"	by 1 in.	
1	No. 2.	"	"	"	by ½ in.	
1	No. 2c.	"	"	"	by ½ in.	
1	Oil Separator, 3 ft. 3 in. dia.					
4	Rolling Mills, with Friction Drive & Countershaft.					
1	Shaft, fitted with Friction Drive for Rolling Mill.					
1	Patent Oil Filter, No. 101, by Wilcox.					
1	Profiling Machine, by Greenwood & Batley.					
1	Disc Grinder, ex. Selson Eng. Co.					
1	Pendulum Saw.					
1	Drilling Machine, ex. Smith & Coventry.					
1	Portable Crane.					
1	Con. Rod Metalling Machine, ex. Burton Griffiths.					
1	Band-Saw Sharpening Machine, ex. Clifton & Waddle.					
1	Oil Separator.					
1	Furnace, Alldays & Onions.					
1	Metal Band-Saw Machine.					
1	Automatic Machine, Pratt & Whitney.					
1	Automatic Screw Machine, Cleveland.					
1	Ten-cwt. Steam Hammer.					
1	Ten-ton Salter Weighing Machine.					
1	Three-ton Salter Weighing Machine.					
1	Plain Milling Machine, 18 ft. by 6 ft., Smith & Coventry.					
1	Drilling Machine Table, 2 ft. 6 in. Spindle, No. 4, Morse.					
1	Capstan Lathe, Pratt & Whitney.					
2	Turret Lathes, No. 2, Bardens & Oliver, 1¼-ins. capacity.					
4	Capstan Lathes, by F. A. Wells & Co., U.S.A., ⅝-in. capacity.					
1	Power-driven Hack Saw, by Millers Falls.					
1	No. 2 Metal Band Saw, by Burton Griffiths.					
1	Plain Grinder, 14 in. by 3 ft. by 6 ft., by H.W. Ward and Son.					
1	3½-in. S.C. Dalton Lathe.					
1	8-in. S.C. Hendy.					
1	Four-Spindle Drilling Machine, by Selson Eng. Co.					
1	Four-Spindle Drilling Machine, by Superior Machine Tool Co.					
1	Lapping and Piston-Ring Machine.					
3	Drummond Lathes, 3½-in. C.S.C.					

Tenders to be lodged not later than Ten a.m., August 20th, 1919. Applications for full particulars of Machines and Plant, to be made to the CONTROLLER, Plant and Machinery Section, Embankment Buildings, Charing Cross, W.C. 2. X 385

G. R.

BY DIRECTION OF THE DISPOSAL BOARD, MINISTRY OF MUNITIONS.

NOTE.—For detailed list of all Surplus Government Property for Sale, apply at the nearest Bookstall or to the Director of Publicity, Ministry of Munitions, Whitehall Place, S.W. for *Surplus*, price 3d.

Marine Engine Cylinders and

MARINE TYPE BOILERS FOR SALE BY TENDER.

One Marine Engine Cylinders, 16 in., 26 in., 44 in. stroke 26 in. Revolutions per minute, 180. Indicated Horse Power, 1400.

Two Marine Type Boilers, 11 ft. 3 in. by 13 ft. dia., 200 lbs. working pressure. Heating Surface, 1825 square feet. Great Area, 51·5 square feet, with three furnaces. Four Marine Type Boilers, 11 ft. 3 in. by 13 ft. diam., 200 lbs. working pressure. Heating surface, 1825 square feet. Great Area, 51·5 square feet, with three furnaces.

Applications for Tender forms should be made to the CONTROLLER, D.B. 1.e., Charing Cross Embankment Buildings, W.C. 2. Tenders must be received by Ten a.m. on August 20th. X 384

APPOINTMENTS OPEN.

UNIVERSITY OF BIRMINGHAM.

APPOINTMENT OF ASSISTANT LECTURER IN MACHINE DESIGN.

Applications are Invited for

this APPOINTMENT. Stipend £250 per annum.

The Candidate selected will be required to enter on his duties on the 1st of October next.

Further particulars may be obtained from the undersigned, to whom applications, accompanied by testimonials, should be sent not later than the 16th of August. X 280

GEO. H. MORLEY,
Secretary.

KENT EDUCATION COMMITTEE.

TECHNICAL INSTITUTE AND DAY CONTINUATION CLASSES, DARTFORD.

Required, in September, an

ASSISTANT MASTER, qualified in Engineering Subjects.

Preference will be given to a candidate with works experience, holding a Degree or Diploma in Engineering.

Initial salary not less than £250. Maximum £300 to £450, according to qualifications and experience.

Forms of application may be obtained from Mr. D. F. Brow, Technical Institute, Dartford.

E. SALTER DAVIES,
Director of Education.

26th June, 1919. W 861

STAFFORDSHIRE EDUCATION COMMITTEE.

BRIERLEY HILL HIGHER EDUCATION COMMITTEE.

Applications are Invited for

the POST of HEAD MASTER of the Technical School, Brierley Hill (South Staffordshire).

A physical chemist is desired, who will be willing to devote himself to the study of the refractory materials and cognate subjects. Works experience will be an advantage.

Initial salary £400 a year.

Further particulars and forms of application, which may be obtained from these offices on receipt of a stamped addressed envelope, should be returned by August 2nd.

GRAHAM BALFOUR,
Director of Education.

County Education Offices, Stafford.
July, 1919. X 329

SUNDERLAND EDUCATION COMMITTEE.

JUNIOR TECHNICAL SCHOOL.

Applications are Invited from

persons with scientific or technical qualifications for the POSITION of HEADMASTER of a Junior Technical School to be opened in October next.

The aim of the School is to give a three years course of pre-apprenticeship training to boys from 13 to 18 years of age. Applicants should possess a University Degree, or its equivalent, and have had teaching and some administrative experience. The nature of any experience in engineering workshops or drawing offices should also be stated.

Applications, accompanied by three recent testimonials and three references, must reach the undersigned (from whom further particulars and forms of application can be obtained) by Monday, August 11th.

Salary:—£400 to £450 by annual increments of £10. Canvassing will be a disqualification.

HERBERT REED,
Chief Education Officer.

Education Offices,
15, John Street,
Sunderland.
July 10th, 1919. X 298

THE UNIVERSITY OF LIVERPOOL. FACULTY OF ENGINEERING.

The Council of the University invite

Applications for the following

POSTS:—

DEPARTMENT OF ENGINEERING.—ASSISTANT LECTURER and DEMONSTRATOR (Mechanical) £250 per annum.

DEPARTMENT OF ELECTRICAL ENGINEERING.—ASSISTANT LECTURER and DEMONSTRATOR (Electric Railways), £300 per annum.

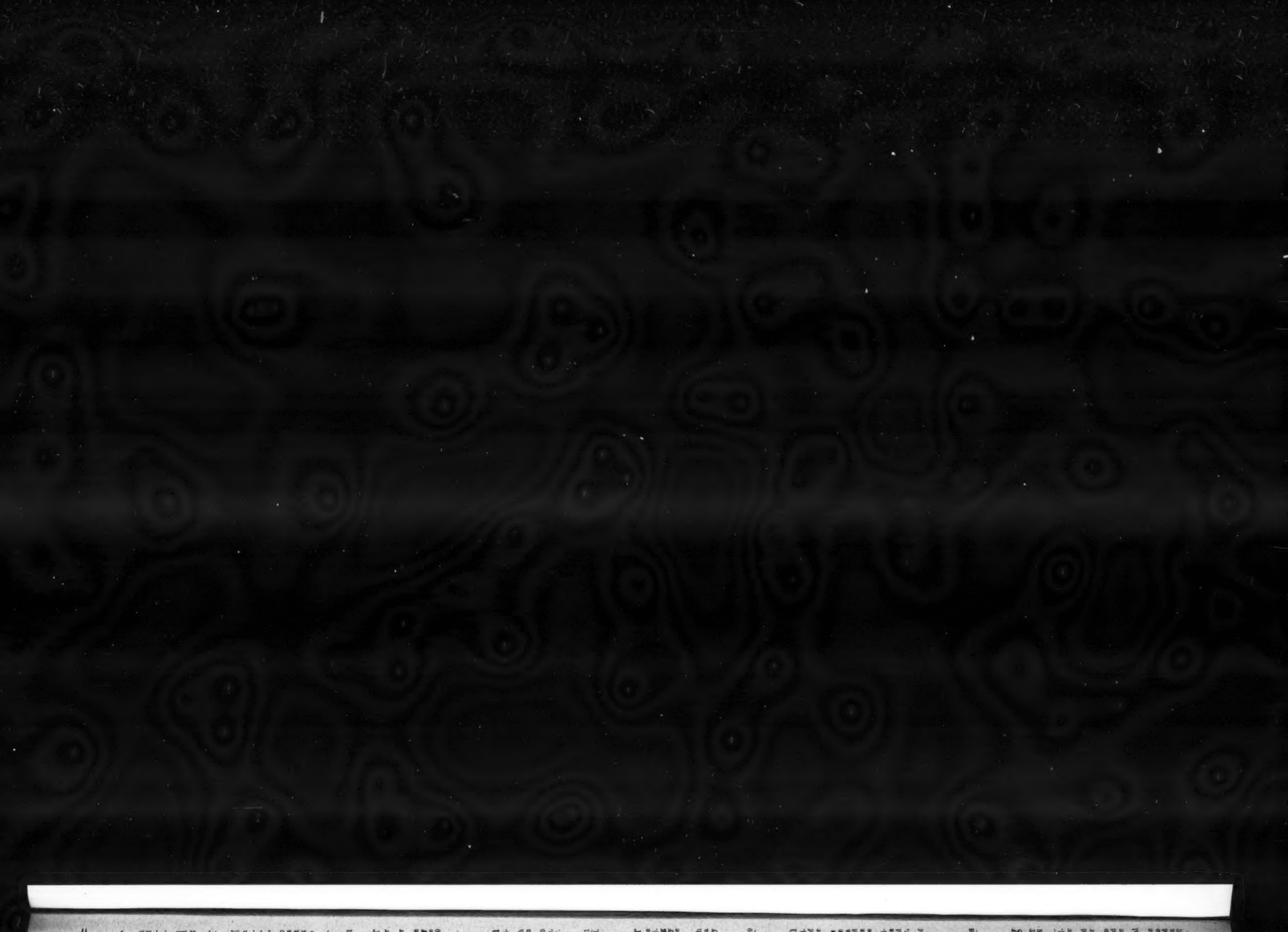
Ditto ASSISTANT LECTURER and DEMONSTRATOR (Telephony), £250 per annum.

DEPARTMENT OF ENGINEERING DESIGN AND DRAWING.—ASSISTANT LECTURER and DEMONSTRATOR (Structures), £250 per annum.

University degree or equivalent, and practical experience necessary.

Applications, with three testimonials and the names of two references, should be forwarded to the REGISTRAR, from whom particulars and conditions of appointment may be obtained, not later than 15th August, 1919. X 307

EDWARD CAREY,
Registrar.



EXACT DATA ON THE RUNNING OF STEAM BOILER PLANTS.

No. 2.—*The Performance of Colliery Steam Boiler Plants and the Saving to be Obtained by their Reorganisation.*

By D. BROWNLIE, B.Sc.Hons.(Lond.), F.C.S.

I PROPOSE to give in this article the exact working details of 100 typical colliery steam boiler-plants in Great Britain as a contribution to the fund of specialised knowledge which it will be necessary to accumulate in order to undertake efficiently the whole question of national coal economy. I hope to show that the average net working efficiency of colliery steam boiler-plants is only about 55·5 per cent., and that by carrying out a reorganisation of these plants on modern scientific lines it is easily possible to run on 70 per cent. This would represent an average saving of about 21 per cent. in the national coal consumption of, say, 18,500,000 tons per annum on colliery plants, corresponding to a saving of no less than about 3,900,000 tons per annum. This saving can be obtained by burning the existing coal more efficiently, but in addition at least another 15 per cent., equal to, say, 2,775,000 tons can be saved by burning refuse coal, so that the total saving would be 36 per cent., equal to, say, 6,600,000 tons per annum.

It is well known that colliery steam boiler-plants, speaking generally, are most inefficient, and in this connection the following extract from the Final Report of the Coal Conservation Committee (Ministry of Reconstruction) is interesting:—

"Final Report of the Mining Sub-Committee, Part II, dealing with 'Loss and Waste of Coal.'

A. *Waste of Coal at Pit-head.*

"The amount of coal consumed at collieries has long been regarded as excessive, but detailed statistics on the subject were not available. We, therefore, thought it desirable to obtain returns from the collieries in the several mining districts of the quantity of coal used by them as boiler fuel, with a view to considering whether the existing steam-raising plant may be regarded as efficient, and whether unnecessary loss of marketable coal is taking place. The returns obtained also deal with the quantity of refuse taken from the coal at the pit-bank and with the quantity of coal recovered in the process of cleaning."

The returns deal with the year 1913, and apply to a gross output of 278,217,295 tons, or 97 per cent. of the total output of the United Kingdom for that year.

B. *Colliery Consumption of Boiler Fuel.*

"Dealing first with the colliery consumption of boiler fuel, and excluding Ireland, the total quantity of coal used for this purpose by the collieries making the returns was 18,395,743 tons, or 6·8 per cent. of the net output plus the coal of which no record of waste was kept.

"The results in the different districts are shown in the following table:—

District.	Output, 1913 (Net) except for that Coal of which no Record was Kept.	Consumption of Boiler Fuel.		Equivalent Coal of Heat from Coke Ovens or Blast Furnaces and from Outside Sources.		Total.
		tons.	per cent.	tons.	per cent.	
Scotland	39,963,822	3,648,189	9·10	132,199	0·33	9·43
Gloucester and Somerset	2,888,251	245,887	8·50	17,323	0·70	9·20
North Wales	3,204,529	270,617	8·40	2,700	0·09	8·49
Lancashire and Cheshire	22,717,604	1,876,686	8·30	36,599	0·16	8·46
Midlands	22,196,664	1,734,452	7·80	72,405	0·32	8·12
Yorkshire, &c., District	68,096,088	3,861,250	5·70	376,158	0·52	6·20
South Wales	53,810,094	3,021,321	5·60	209,059	0·40	6·00
Northern District	57,540,366	2,180,937	3·80	692,959	1·20	5·00
Kent	52,416	17,002	32·4	—	—	32·40
Totals	270,469,834	16,856,341	6·2	1,539,402	0·57	6·8

"It will be observed that the highest percentage of consumption (excluding Kent) is 9·43 per cent. in Scotland, and the lowest, 5 per cent., in the Northern district."

"In judging of the relative consumption of coal for boiler fuel in the different districts, it is necessary to take into account the difference in the calorific value of the coal used; and also the varying conditions under which the collieries are worked—the depth of the pits, the length of mechanical haulage underground, the quantity of water to be pumped, the pressure of firedamp, restricting the use of electricity for underground power and necessitating a larger amount of ventilation, the supply of waste heat in the district, the relative size of the collieries, the existence of antiquated and extravagant steam-raising plant, and many other special circumstances affecting particular mines. Many of these conditions must be accepted as natural and unavoidable in the working of collieries, but the existence in a coalfield of a large number of collieries too small to be worked economically, and the survival of antiquated and extravagant plant may be regarded as avoidable causes of waste."

As regards the question of "lack of statistics," this is, to some extent, correct, as although a very large amount of writing and lecturing has just recently been undertaken by various people, most of this amounts to very little more than pious platitudes and expressions of opinion entirely unsupported by facts.

The firm with whom I am associated have been continuously engaged in investigating and re-organising the working of steam boiler-plants, especially colliery plants, for the last eight or nine years, and in the course of this important work we have accumulated a considerable amount of original information with regard to the working of colliery steam boiler-plants. I published an article in *The Colliery Guardian*, March 1, 1918 ("Coal Saving at Collieries by Economical Steam Raising"), giving the average figures for the performance of 75 "typical" colliery steam boiler-plants situated in South Wales, Lancashire, Yorkshire, Derbyshire, Nottinghamshire and Gloucestershire.

I should add that the results apply to "typical" colliery boiler-plants only run on the following lines:—"Lancashire" boilers, which may or may not be suitably insulated, working in the open air, with chimney draught and hand-firing. There may or may not be some form of steam jet "patent" furnace bar. The feed-water heated up by the exhaust steam of the winding and other engines and pumped hot into the boilers without any other treatment. The feed-water generally bad in quality, and apt to give corrosion troubles, as well as scale.

Also I published in ENGINEERING, July 12 and 19, 1918 ("Coal Saving by the Scientific Control of Steam Boiler-Plants"), average figures for the performance of 250 typical steam boiler-plants from 27 different industries (including 75 colliery plants), which I contend are more or less typical for the whole of the industries of Great Britain. These figures in detail are given in the Table annexed.

The results I have already published show, therefore, that the average net working efficiency of "typical" colliery steam boiler-plants is only 51 per cent. as against 60 per cent. for the whole country, so that if "typical" colliery steam boiler-plants were only run as efficiently as the general average for all industries the saving alone would be 15 per cent.

The question of coal economy at collieries is now even more important than ever, because of the great additional expense in the working of collieries due to increased wages and cost of material, and because of the enormously increased value of coal. For this reason, and in order to prove the very great saving that can be obtained by re-organising colliery steam boiler-plants on modern lines, I have given attached, in the form of a huge table, on Plate IV, published in this issue, the separate detailed figures for the performance of 100 colliery boiler-plants, including due proportion of the more up-to-date plants fitted with economisers and superheaters, which, I think, are thoroughly representative of Great Britain, and which have been obtained during our past eight years' work on this question.

—	Average Figures of 250 Typical Steam Boiler Plants in Great Britain Representative of all Industries (including 75 Colliery Plants).	Average Figures of 75 Typical Colliery Steam Boiler Plants in Great Britain.
A.—Working-Day Test.		
Duration of test (hours)	9·43	8·44
Type of boiler	Practically "Lancashire"	"Lancashire"
Number of boilers (average)	4·0	6·14
Dimensions of boilers	Average about 30 ft. by 7 ft. 6 in.	30ft. by 8 ft. 6 in.
Total grate area (sq. ft.)	152·6	239·7
Method of firing	24 per cent. mechanical firing	Hand
Number of tubes in economiser	Not given as an average	None
Number of tubes wide	,,	Nil
Analysis of coal burned—		
British thermal units	11,822	10,920
Ash (per cent.)	11·5	16·5
Amount of coal burned (lb.)	30,131	41,851
Coal burnt per boiler per hour (lb.)	798·8	807·6
Coal burnt per square foot grate area per hour (lb.)	20·9	20·7
Draught chimney base	0·80 in. W.G.	0·83 in. W.G.
Draught, side flues	0·40 in. W.G.	0·46 in. W.G.
Temperature of flue gases before economiser	598 deg. F.	634 deg. F.
Temperature of flue gases after economiser	478 deg. F.	Nil
Percentage CO_2 in side flues	7·6	8·0
Total water evaporated (lb.)	197,776	226,650
Water evaporated per boiler per hour (gallons)	524	437
Temperature of feed-water before economiser	116 deg. F.	163 deg. F.
Temperature of feed-water after economiser	193 deg. F.	Nil
Saving due to economisers	7·1 per cent.	No economisers
Steam pressure, gauge (lb. per sq. in.	89	82
Temperature of saturated steam	330·5 deg. F.	325·4 deg. F.
Temperature of superheated steam	346·5 deg. F.	Nil
Amount of steam or power used as auxiliary to the production of steam (per cent.)	2·4	1·5
Water evaporated per pound of coal (lb.)	6·56	5·40
Water from and at 212 deg. F., evaporated per pound of coal (lb.)	7·46	5·80
Water from and at 212 deg. F. evaporated per 10,000,000 B.T.U. (lb.)	631·0	531·1
Efficiency of Plant—		
A. Net working efficiency after deducting steam or power used as auxiliary to the production of steam (per cent.)	60·09	51·20
B. Efficiency of boilers only (per cent.)	56·71	52·00
C. Efficiency of economisers only (per cent.)	4·35	Nil
D. Efficiency of superheaters only (per cent.)	0·51	Nil
B.—Long Check Test.		
Duration of test (hours)	167·50	168·00
Amount of coal burnt (tons)	128·25	196·50
Total water evaporated (gallons)	184,435	231,250
Water evaporated per pound of coal	6·42	5·25
Approximate annual coal bill (tons)	6,500	9,925

I may say that we have inspected, without testing, hundreds of colliery boiler-plants, and as a result of this experience, I am confident that the 100 plants are a good average selection, and typical of the whole country. Before considering the figures in detail, I should like to point out that, as already stated in previous articles, in each case a complete scientific investigation was carried out into the working of the plant, comprising a detailed test of about, say, eight hours, representing the period of the daily "wind," and a further long test of one week inclusive, as a check on the figures for the coal used and the water evaporated. This long check test is also valuable as a means to ascertain the actual running conditions from week to week, including all losses due to stoppage at week-ends, lighter running at night, &c.

The object of the investigation is to find out the exact normal every-day working conditions of the

plant, particularly as regards efficiency and the cost in coal for a unit of steam (evaporation of 1,000 gallons of water) so that a scheme of re-organisation could be devised for the more economical production of steam.

In every case the boiler-house staff worked the plant as usual, and at the end of the test the water level in the boilers and the general conditions of the fires were the same as at the commencement. The coal used was sampled with the greatest care, and the heating value direct as fired determined with the oxygen-bomb calorimeter, whilst the percentage of ash was determined in the muffle furnace. The evaporation was determined with a well-known make of pressure-type water-meter calibrated before each test, and we also fitted on the plant for the week a combustion-recorder and thermo-electric pyrometer for the flue gases. In cases where steam-jets were used, we determined exactly the amount of steam used with an apparatus of our own, in which the steam issuing from the nozzles is condensed in cooling coils and weighed direct as water. I have not given the figures for the cost of evaporation, because of the great fluctuations in the cost of the coal and the difficulties of placing a proper value on those coals which are purely refuse coals, and also on coals which it is very difficult to classify as saleable or not.

I have arranged the figures in the table on the principle we adopt in giving a detailed report on the working of a boiler-plant, namely, first a general account of the plant in the way of full particulars of boilers and economisers, grate area, method of firing, &c. Where boilers of different dimensions are installed, I have given the nearest average size to save space.

Then follow the particulars relating to the coal, such as the amount burnt, the heating value and percentage of ash, the draught, black smoke, temperature of flue gases, and the percentage of CO_2. Following this, we have the particulars relating to the water evaporated, the amount, the temperature, the chemical analysis for hardness, the steam pressure, the amount of superheat, and the amount used as auxiliary to the production of the steam, which has to be deducted from the actual steam output of the plant. I have given briefly, in the references, the essential features of each steam-jet apparatus in use as far as space will allow.

The next item is the final results, the evaporation per lb. of coal, both at the given temperature and "from and at" 212 deg. F. We have always included the figure "lbs. water from and at 212 deg. F., per 10,000,000 B.T.U." because the ordinary figure, "from and at 212 deg. F." is really of little use as it takes no account of the heating value of the particular coal which may be anything from, say, 8,000 to 14,500 B.T.U. We give the efficiency figures in detail, namely the exact net working efficiency of the combined plant (after deducting the steam or its equivalent used in the actual generation of steam), and the separate efficiencies of the boilers, economisers and superheaters. Then follows the long check test of one week's duration. In a number of cases the figures do not agree exactly with the day's test, but the reason of this is the great fluctuation in the quality of the coal from day to day.

I have arranged the plants in order of merit (net working efficiency) giving the district in which each plant is situated, and I trust that the figures will be easy to follow. In such a mass of figures it is almost impossible to avoid errors, but I have done my best in the way of laborious checking to reduce errors to a minimum.

I have also attempted a very difficult task, namely, to give a true average for the whole 100 plants, with the object of giving figures which can be conveniently taken as average representative performance of all the colliery steam boiler-plants of the country (at any rate until further information is available). It is obvious, of course, that to add up all the figures in each column in the table and divide by 100 will be of little use if only because of the different sizes of the plants and the varying duration of the tests. The correct method in the case of the weights of the water evaporated and the coal burnt is to reduce each plant to a common factor of, say, eight hours and then to add the totals. That is, the whole 100 plants must be regarded as one huge boiler-plant. In the case of the other essential figures of the real average for the B.T.U., the temperature of the feed-water before and after the economiser, the steam pressure, the degree of superheat, and the percentage of auxiliary steam, these can only be obtained as follows:—After the coal and water figures have been adjusted in each case to eight hours, the figures for the B.T.U. and the weight of the coal must be multiplied together, the total 100 results added up, and the result divided by the total weight of the coal of the 100 results, giving the real average B.T.U. In the same way for all the other essential figures the weight of the water evaporated must in each case be multiplied by the particular steam pressure, degree of temperature of steam, temperature of feed-water, &c., the total 100 results added up and the results divided by the total weight of the water of the 100 results, giving in this way the true average in each instance. The same general method applies to the other figures, such as the draught and the temperature of the flue gases.

REFERENCES TO TABLE ON PLATE IV.

(A) Eight steam jets ($\frac{1}{4}$ in.) per boiler. Full steam pressure.
(B) Ten steam jets ($\frac{1}{4}$ in.) per boiler. Full steam pressure.
(C) Sixteen steam jets ($\frac{1}{16}$ in. to $\frac{1}{8}$ in.) per boiler. Full steam pressure. Two boilers only.
(D) Eight steam jets ($\frac{1}{4}$ in. to $\frac{1}{2}$ in.) per boiler. Full steam pressure.
(E) Fourteen steam jets ($\frac{1}{2}$ in.) per boiler. Full steam pressure.
(F) Sixteen steam jets ($\frac{1}{16}$ in. to $\frac{1}{8}$ in.) per boiler. Full steam pressure.
(G) Induced draught.
(H) Forty steam jets ($\frac{1}{2}$ in. to $\frac{1}{16}$ in.) per boiler. Full steam pressure.
(I) Four steam jets ($\frac{1}{4}$in.) diameter per boiler. Full boiler pressure.
(K) Four steam jets ($\frac{1}{2}$ in.) diameter per boiler. Full boiler pressure.
(L) Eight jets ($\frac{1}{16}$ in. to $\frac{1}{8}$ in.) holes per boiler. Steam pressure reduced to about 40 lb. Four boilers only.
(M) Eight steam jets, $\frac{1}{2}$ in. per boiler. Full boiler pressure.
(N) Four steam jets ($\frac{1}{2}$ in.) per boiler. Full boiler pressure.
(O) Sixteen steam jets ($\frac{1}{16}$ in.) per boiler. Full boiler pressure.
(P) Six steam jets ($\frac{1}{8}$ in.) per boiler. Full boiler pressure.
(Q) Eight steam jets per boiler ($\frac{1}{4}$in. to $\frac{1}{2}$ in.). Steam pressure reduced to about 40 lb.
(R) Six steam jets ($\frac{1}{2}$ in.) per boiler. Full boiler pressure.
(S) Eight steam jets per boiler ($\frac{1}{2}$ in.). Full boiler pressure.
(T) Eight steam jets per boiler ($\frac{1}{16}$ in. to $\frac{1}{8}$ in.). Steam pressure reduced to about 40 lb., one boiler only.
(U) Eight steam jets per boiler ($\frac{1}{16}$ in. to $\frac{1}{8}$ in.). Steam pressure reduced to about 30 lb.
(V) Sixteen steam jets ($\frac{1}{16}$ in. to $\frac{1}{8}$ in.) diameter per boiler. Full steam pressure. Two boilers only.
(W) Forty-two steam jets ($\frac{1}{16}$ in.) per boiler.
(X) (Two boilers only). Eight steam jets per boiler ($\frac{1}{2}$ in.). Full steam pressure.
(Y) Four steam jets per boiler ($\frac{1}{4}$ in.). Full boiler pressure.
(Z) Eight steam jets ($\frac{1}{2}$ in.) per boiler. Full boiler pressure.
(AA) Eight steam jets ($\frac{1}{2}$ in.) per boiler. Full boiler pressure.
(BB) Forty steam jets ($\frac{1}{16}$ in.) per boiler. Full boiler pressure.
(CC) See above. Cannot be given as an "average." 71 per cent. natural draught, 26 per cent. steam jets, 3 per cent. induced draught, 0.0 per cent. forced draught.
(DD) Cannot be given as an "average." 49.2 per cent. natural draught, 37.2 per cent. steam jets, 12.8 per cent. induced draught, 0.8 per cent. forced draught.
(1) Great variation in quality of coal.
(2) Great variation in quality of coal.
(3) Much variation in quality of coal.
(4) Difficulty in weighing the coal,
(5) Difficulty in weighing the coal.
(6) Difficulty in weighing the coal.
(7) Difficulty in weighing the coal.
(8) Difficulty in weighing the coal.
(9) Difficulties in emptying the firehole.

The whole is on a somewhat laborious and complicated proceeding, but it is worth the trouble, if only as a means of comparing the efficiency of colliery steam boiler-plants with the general industries of the country. I have given for this comparison similar average figures for 250 boiler-plants, comprising the following industries:—Bleaching, brewing, calico-printing, carpet manufacture, chemical (general), collieries (75 plants), cotton manufacture, dyeing, dyeing and cleaning, electric power station, engineering, explosives, flour-milling, food products, hat manufacture, hosiery manufacture, hospitals, hotels, lace manufacture, laundries, leather manufacture, linen manufacture, paper manufacture, potteries, soap manufacture, steel manufacturing and woollen manufacture, which, I think, is a fairly comprehensive selection.

DETAILED ANALYSIS OF THE RESULTS OF THE 100 TESTS.

1. *Type of Boilers.*—The 100 plants have a total of 570 boilers, comprising 500 "Lancashire" boilers, two "Cornish" boilers, 37 "Egg-Ended" boilers, and 31 modern "Tubular" boilers. The typical colliery boiler to-day is undoubtedly the "Lancashire" boiler (as, in fact, it is of most industries) of an average size of about 30 ft. by 8 ft. 6 in. Collieries seem to go in for particularly large boilers, 30 ft. by 9 ft. being commonly installed, and in a number of cases boilers 30 ft. by 10 ft.

The extremely low efficiency of the old "egg-ended" boiler will be noted, the average being less than 35 per cent. as against, say, 55 per cent. for "Lancashire" boilers. Thus the mere substitution of "Lancashire" boilers for "egg-ended" boilers alone would reduce the coal bill about 35 per cent. in the case of a colliery working with "egg-ended" boilers only. There seems to be still a fair number of these boilers at work in spite of their shocking inefficiency, and not many years ago they were regarded as good colliery practice. It will also be noted that the few modern "tubular" boilers installed are, on the average, giving no better results than the "Lancashire" boilers.

2. *Amount of Coal used.*—The total annual coal consumption, on the whole 100 plants, is approximately 1,250,000 tons. As already seen, the coal bill for all the colliery boiler-plants in the country is about 18,500,000 tons. Averaging all the plants up in terms of "Lancashire" boilers 30 ft. by 8 ft. 6 in., this corresponds to approximately 730 lbs. of coal per boiler per hour, and 19 lbs. of coal per square foot of grate area per hour, as against 798·8 lbs. and 20·9 lbs. for the 250 tests.

Although the figures in this respect for colliery plants are inferior, it must be remembered that the quality of coal used is generally somewhat worse than in other industries. The boiler-plant of the average colliery of this country is burning much less coal per boiler than is possible with the best working efficiency, and the steam required for collieries could be obtained for a much smaller number of boilers. The same applies to most other industries, but collieries are probably the worst in this respect.

3. *Quality of Coal Used.*—There is a general idea that collieries burn only refuse and inferior coal not fit for sale, and that, therefore, any improvement in efficiency would be of no advantage. Thus, in the Final Report of the Coal Conservation Committee ("Colliery Consumption of Boiler Fuel") the following statement is made:—

"The policy of collieries has been to set free the best qualities of coal for the market, and to retain for colliery consumption the poorest quality. The returns show that the quantity of ash in some of the fuels used ranges from 50 per cent. to 80 per cent."

In view of this statement it will be very interesting to analyse the results obtained for the quality of the coal used on the 100 plants. In the first place the true mathematical average figures for the 100 colliery boiler-plants are 10,500 B.T.U and 15·5 per cent. ash, as compared with the figures for 250 typical boiler-plants of 11,822 B.T.U. and 11·5 per cent. ash. The quality is not, therefore, so very much worse than the average coal burnt in all industries.

Apart from boiler plant work, we have analysed hundreds of samples of coals from collieries, and I have never heard of a case of 50 per cent. to 80 per cent. ash as mentioned in the Report. Such an instance must be extremely rare, and the statement as it appears is most misleading.

Fifty-two per cent. of the coal is high-grade coal, and, in my opinion, of the remainder 32 per cent. could be used economically in industry for steam generation after the cost of carriage is taken into account. On the total national coal bill of 18,500,000 tons, this would correspond to 9,620,000 tons of high-class coal, 5,920,000 tons medium quality, and 2,960,000 tons refuse coal. Details are given in the Tables on the next page.

That is to say, only 16 per cent. of the coal burnt was definitely unsaleable, and of this amount the highest percentage of ash was 35 per cent.

I maintain that these results are typical of the colliery industry, and the idea that collieries burn chiefly refuse and unsaleable coal is a complete fallacy.

As a matter of fact, there are millions of tons of refuse coal lying unburnt at collieries, and a very large proportion of this refuse could be utilised for steam generation, as we have proved ourselves on a number of colliery plants. The carrying out

1. *Definitely Saleable Coal of Equal Average Quality to that Generally Used for Steam Generation before the War throughout the Country.*

—	Quality of Coal.	Coal Bill per Annum.
		tons.
A.	Coal over 13,000 B.T.U.	45,000
B.	Coal 12,000 B.T.U. to 13,000 B.T.U. ..	335,000
C.	Coal 11,000 B.T.U. to 12,000 B.T.U. ..	120,000
D.	Coal 10,000 B.T.U. to 11,000 B.T.U. ..	150,000
	Total	650,000

This corresponds to 52 per cent. of the total coal bill of 1,250,000 tons per annum on the 100 plants.

2. *Coal Not Definitely Saleable, but which could be Economically Used for Steam Generation, and which is Equal in Quality to Much of the Steam Coal Sold since the Outbreak of War.*

—	Quality of Coal.	Coal Bill per Annum.
		tons.
A.	Fine anthracite, 12,750 B.T.U. to 14,150 B.T.U.	47,500
B.	Coal, 10,200 B.T.U. to 11,540 B.T.U., but containing a fair amount of unburnable material	182,500
C.	Coal, 9,240 B.T.U. to 10,000 B.T.U., containing a considerable amount of unburnable material	170,000
	Total	400,000

This corresponds to 32 per cent. of the total coal bill of 1,250,000 tons per annum on the 100 plants.

3. *Definitely Unsaleable and Refuse Coal.*

—	Quality of Coal.	Coal Bill per Annum.
		tons.
A.	B.T.U. from 6,792 to 9,873, and containing an enormous percentage of ash, together also in many cases with excessive moisture	200,000

This corresponds to 16 per cent. of the total coal bill of 1,250,000 tons per annum of the 100 plants.

RESULTS OF TESTS OF 100 COMMERCIAL BOILER PLANTS.

—	20 Cotton Mills.	10 Lace Mills.	16 General Chemical Manfrs.	22 Explosive Factories.	26 Dyers and Bleachers.	21 Woollen Mills.	9 Hosiery Mills.	21 Paper Mills.
Duration of trial .. .. hours	11·15	9·14	7·98	17·66	8·87	8·6	8·29	11·35
Amount of coal used .. lb.	28,773	13,897	11,939	210,741	17,744	17,462	15,251	37,558
Price of coal per ton (taken as) ..	20s.	20s.	20s.	20s.	20s.	20s.	20s.	20s.
Analysis of coal used—								
British thermal units	12,972	10,249	11,669	12,359	12,355	12,617	10,683	12,347
Ash .. .. per cent.	8·4	12·4	11·2	9·67	8·5	11·0	9·5	10·6
Coal burnt per boiler per hour, lb.	806·4	661·0	680·0	1075·0	778·3	822·0	766·5	787·8
Water evaporated .. lb.	213,606	69,059	77,000	1,581,480	114,241	119,973	89,243	294,933
Water evaporated per pound of coal .. .. .. lb.	7·42	4·96	6·45	7·50	6·43	6·87	5·85	7·85
Equivalent evaporation from and at 212 deg. F. per pound of coal .. .. .. lb.	8·54	5·70	7·28	8·78	7·39	7·88	6·72	8·83
Temperature of feed water before economisers .. ..deg. F.	110·0	96·0	121·0	89·5	98·0	109·0	105·0	133·0
Temperature of feed water after economisers .. ..deg. F.	250·5	126·0	199·0	183·0	207·0	237·0	186·0	261·0
Coal bill saved by economisers, per cent.	12·8	2·75	7·30	8·4	9·9	11·7	7·4	11·9
CO_2 .. .. .. per cent.	8·1	6·5	8·0	8·7	8·2	7·1	7·0	8·2
Steam pressure (gauge) .. lb.	124·0	56·0	71·0	118·0	59·0	94·0	80·0	113·0
Temperature of saturation of steam .. .. ..deg. F.	352·0	304·0	317·0	349·0	307·0	333·9	323·9	345·9
Temperature of superheated steam .. .. ..deg. F.	415·0	—	357·0	401·0	320·0	345·4	346·6	412·8
Steam used as auxiliary, per cent.	1·1	0·3	0·71	5·68	1·7	2·8	3·0	1·2
Thermal efficiency—								
A. Net working efficiency after deducting steam used as auxiliary .. per cent.	64·97	53·76	61·0	66·48	57·20	58·97	59·57	70·67
B. Boilers only	55·49	52·44	55·89	62·98	52·10	53·24	56·23	60·87
C. Economisers only	8·18	1·48	4·39	5·77	5·77	7·09	4·51	8·28
D. Superheaters only	2·02	nil	1·15	1·73	0·31	0·34	0·66	2·38
Cost in coal to evaporate 1,000 gallons of water per hour, pence	144·3	215·6	166·1	142·4	166·4	155·9	183·1	136·4

of such a proposition results in an enormous saving in the coal consumption, after allowing ample deduction for the cost of the extra boilers, and plant necessary because of the low calorific value.

4. *Price of Coal Used.*—As already stated, it is extremely difficult to give the real value of the coal used on colliery steam boiler-plants.

According to the evidence given before the Coal Inquiry Commission by Mr. A. L. Dickinson, Chairman of Finance Board and Financial Adviser to the Coal Controller, the average value per ton of the coal raised for different years is as follows :—

	s.	d.
1908–1913	8	9
1914	9	11¼
1915	12	5½
1916	15	7½
1917	16	8½
1918	24	10

According to these figures, therefore, the 52 per cent. of the coal burnt on colliery boiler-plants, that is 9,620,000 tons per annum, is worth to-day 24*s.* 10*d.* per ton, whilst 32 per cent., or 5,820,000 tons, of moderate quality is in proportion worth at least 20*s.* per ton. The purely refuse coal, 16 per cent. of the total, equals 2,960,000 tons, is worth its equivalent of saleable coal replaced on the colliery boiler-plants. That is to say, if three tons of such refuse coal is in practice equal to about one ton of saleable coal, after taking in account extra labour, plant and depreciation, then the value of such refuse coal to-day would be about 8*s.* per ton.

A fair average price for the whole of the coal burnt on colliery boiler-plants, irrespective of quality, would be to-day about 20*s.* per ton, that is to say, the coal bill of the whole colliery industry is 18,500,000*l.* per annum.

5. *Method of Firing.*—The almost universal practice on colliery boiler-plants is hand firing, and, in my opinion, this is the correct method for "Lancashire" boilers, if only because of the greatly varying character of the coal used at most collieries. In the 100 plants only five were mechanically fired, and the average results were, if anything, slightly inferior to hand-firing, quite apart from the cost of upkeep of the stokers.

The figures for the 250 plants show 24 per cent. mechanical-firing, but we are badly in need of a proper engineering census in order that points such as these may be known with certainty in every industry.

6. *Measurement of Boiler Feed-Water.*—In all the 100 plants in not one case was any apparatus installed for determining regularly the water evaporated, that is the amount of steam produced. In every case we had to install our own water meter in order to find out what the plants were actually doing in the way of amount of steam produced.

As I have pointed out in various articles a boiler-plant is a little factory in itself, in which the finished product is steam (just as in the case of a colliery the finished product is coal), and unless there is some form of water-measuring apparatus to check the performance of the plant, there is bound to be a loss, as any process that is worked in the dark is bound to be losing *some* money. It is impossible to get the most economical results out of any boiler-plant unless a water meter is installed, and there are very few colliery boiler-plants in this country, probably not 1 per cent., which are equipped in this way.

7. *Amount of Water Evaporated.*—The average figure for the 100 plants shows approximately an evaporation of 393 gallons per boiler per hour, which calculated in "Lancashire" boilers of standard size, 30 ft. by 8 ft. 6 in., corresponds to about 400 gallons per hour. The figure for the 250 plants typical of all industries is about 600 gallons for this size of "Lancashire" boiler.

As already stated ("2. Amount of Coal Used") colliery boiler-plants are burning much less coal per boiler than could be utilised by modern methods of steam generation. Thus a "Lancashire" boiler 30 ft. by 8 ft. 6 in. with coal of an average quality of, say, 11,000 B.T.U. per lb., can be made to burn 1,000 lbs. to 1,200 lbs. per hour, and to evaporate with the highest economy 800 gallons per hour, which in the case of collieries would represent an increase of 100 per cent. in the evaporation.

In most cases 25 per cent. to 50 per cent. of the boilers in operation at collieries could be shut down and the same amount of steam generated with much greater efficiency from the remaining boilers. In the past, hundreds of additional boilers have been put down at collieries which were quite unnecessary, because no one had any idea what the already existing plant was doing, and what was possible with a plant run on correct lines.

These remarks, of course, apply to fairly good quality coal, such as is usually burnt at collieries, and not to purely refuse coal. As already stated, in many cases it would pay to still further increase the boiler capacity, and burn refuse coals now thrown away, but at the present time whatever quality of coal is being burnt, the amount per square foot of grate area per hour is much too low.

8. *Analysis of Feed-Water.*—The average figures for the feed-water as actually going into the boilers on the 100 tests are 9·5 grains per gallon permanent hardness, and 2 grains per gallon temporary hardness. This average is much less than might have been expected, and, in fact, is only about the same as that in all industries generally. There is, however, very great variation in the quality of boiler feed-water used at collieries, and some of the water is shocking in quality, so that there are more "chronic" cases than in any other industry.

Thus, in the 100 tests we have cases of 32, 28, 25, 22, 21, 19, 18 and 16 grains per gallon total hardness, and with conditions like this it is hopeless to get efficient results because of the accumulation of scale. Fifty-eight of the plants have a hardness of 10 deg. or over, and some proper treatment is required to get the best results.

Like all other industries, collieries have not realised the necessity of treating the boiler feed-water on correct lines in order to obtain coal economy. Further, collieries have peculiar troubles of their own because of sulphuric acid in the pit water due to the oxidation of the pyrites in the coal, and many collieries have most serious corrosion difficulties on this account. It would be very interesting to know how many thousands of pounds the colliery industry has lost in the way of damaged boilers because of this, all of which could have been saved by installing a proper plant for the treatment of the feed-water.

9. *Temperature of Boiler Feed-Water.*—The common practice in collieries is to heat up the feed-water by means of exhaust steam from the winding and other engines, about 80 per cent. of the plants tested adopting this method. The modern scientific practice is to utilise in a mixed pressure turbine the large amount of exhaust steam available, but most collieries still have no other use for this valuable exhaust steam except to use part of it to heat up the feed-water. It is generally supposed that by this means the feed-water enters the boilers at a temperature of nearly boiling point, that is to say 200 deg. F., or over. In practice, however, the temperature rarely exceeds an average of 180 deg. F. at any particular colliery, and the average for the 80 plants is only about 160 deg. F.

10. *Economisers.*—Most colliery steam boiler-plants are not fitted with economisers, and have no means of utilising the waste heat in the flue gases. As seen from the figures, in the 100 plants, 18 are equipped. Economisers installed on modern

lines will reduce the coal bill, say, 17·5 per cent. under average conditions. On the above 18 plants, only six plants are obtaining good results, that is a saving of over 11 per cent., whilst eight of the plants are obtaining results of less than 7·5 per cent.

Even when economisers are installed at collieries, they are generally in a neglected condition, and in most cases badly designed. Speaking generally, probably at least 15 per cent. of the coal bill could be saved in the colliery industry by the installation of economisers on correct scientific lines.

11. *Method of Draught.*—The general practice in collieries is to work with ordinary chimney draught. This is, no doubt, partly explained by the general practice of working without economisers, so that as seen the average temperature of the gases in the chimney base is about 690 deg. F. With such conditions, a good draught is obtained with a chimney of moderate height, but the fact that as a result of this, 15 per cent. to 20 per cent. of the coal burnt is wasted as heat up the chimney, has not been considered.

In the 100 tests, three plants were being worked with mechanical (induced) draught, and this probably represents about the proportion of mechanical draught colliery plants in the country. A chimney as a draught-producer, is a thoroughly out-of-date, unscientific, and wasteful apparatus, and a good draught is only obtained at the cost of a shocking waste of heat.

12. *Estimation of CO_2.*—The figures obtained can be summarised as follows, the average being 7·5 per cent.:—

100 Colliery Plants.		250 Plants. Typical of all Industries.
		per cent.
1. Very good (over 12 per cent.) ..	1	1·6
2. Good (10 per cent to 12 per cent.)..	4	6·8
3. Medium (8 per cent. to 10 per cent.)	23	25·6
4. Poor (5 per cent. to 8 per cent.) ..	61	57·6
5.*Very bad (under 5 per cent.) ..	9	8·4

* In two plants the figures were not determined.

In this respect colliery boiler-plants are about equal to the other industries of the country.

A plant worked on correct lines, and with an average quality of coal should give 10 per cent. to 12 per cent. CO_2 with hand-firing, and figures less than this indicate losses in efficiency due to bad firing or leaky brickwork. There is, therefore, considerable room for improvement in this direction on colliery boiler-plants, and it is impossible to get the most economical results unless some form of gas-analysing machine (combustion-recorder or indicator) is installed on the plant as a guide to the firemen. Very few colliery plants in the country are equipped with reliable apparatus of this description, and of the 100 plants tested, only three were fitted.

13. *Boiler Pressure.*—The average working pressure of the 100 plants is 86 lbs. per square inch, and the figures can be summarised as follows:—

100 Colliery Plants.		250 Plants. Typical of all Industries.
		per cent.
1. Over 160 lb. pressure	None	2·8
2. Over 120 lb. to 160 lb.	9	14·8
3. Over 100 lb. to 120 lb.	7	14·0
4. Over 80 lb. to 100 lb.	25	22·0
5. Over 60 lb. to 80 lb.	38	28·4
6. Below 60 lb.	21	18·0

The question of the working pressure is not of much importance in connection with the economical *generation* of steam, but regarding the question of economy by the economical *utilisation* of steam, a serious loss is undoubtedly caused by the steam pressure of colliery equipment generally being much too low. It will be noted that the average for all industries is 89 lbs., so that collieries are about average in this respect.

14. *Superheaters.*—The colliery industry makes a very poor use of superheaters, only 19 plants being equipped out of the 100. Of these a number are only partly equipped, so that the average for the 100 plants is only 21·6 deg. F. superheat. Here, again, the colliery industry is about the same as other industries, and this method of improving the efficiency is greatly neglected.

15. *Steam or Power Used as Auxiliary to the Production of Steam.*—As seen, out of the 100 plants tested, 26 were fitted with some form of apparatus having steam jets blowing under or over the furnaces. Generally speaking, most of these appliances are very wasteful, and on the 26 plants the amount of steam being used varies from 1 per cent. to 15·25 per cent. of the production. Also three plants were fitted with induced draught equipment. The true mathematical average for the whole 100 plants works out at 1·8 per cent. of the production, including 74 plants not equipped, the colliery industry in this respect being better than the average.

16. *Efficiency of Plant.*—The true mathematical average for the 100 plants is 55·52 per cent. net working efficiency.

The figures can be summarised as follows:—

100 Colliery Plants.			250 Plants. Representing all Industries.
			per cent.
1. Over 65 per cent.	5		21·6
2. 60 per cent. to 65 per cent. ..	8		17·6
3. 55 per cent. to 60 per cent. ..	29		24·8
4. 50 per cent. to 55 per cent. ..	28		18·8
5. 45 per cent. to 50 per cent. ..	22	35	17·2
6. Under 45 per cent.	13		(less than 50)

Divided into districts the results are as follows:—

District.	Number of Plants Working at the following Net Efficiencies.						Total No. of Plants.
	Over 65 per cent.	60–65 per cent.	55–60 per cent.	50–55 per cent.	45–50 per cent.	Under 45 per cent.	
Derbyshire	—	—	1	5	2	—	8
Gloucestershire ..	—	—	—	1	—	—	1
Lancashire	1	1	4	5	2	—	14
Notts ..	—	—	1	2	3	1	7
Shropshire ..	—	—	—	—	1	—	1
Scotland ..	—	1	3	—	2	2	8
South Wales	3	3	3	2	3	3	17
Staffs. ..	—	2	13	4	3	4	26
Warwickshire ..	—	—	—	1	—	—	—
Yorkshire ..	1	1	4	3	6	2	17
Total ..	5	8	29	23	22	13	100

It is very clear, therefore, that the colliery industry is considerably worse than the average, being 55·52 per cent. against 60 per cent. for all industries (including 75 collieries).

In the original article ("Coal Saving by the Scientific Control of Steam Boiler Plants") I gave figures for various industries (see previous page).

The reason why collieries are about the worst of all industries in this respect is obviously because in the past coal has been so cheap as to be hardly worth saving. Only a very few years ago in some districts in Great Britain, high class coal was sold at 5*s* per ton, and collieries have actually given coal away to release railway wagons. With coal however at 24*s*. 11*d*. per ton, conditions are vastly different, and the amount of coal consumed at the boiler plant is a serious matter. From a long experience of industrial conditions generally I have no hesitation in saying that the colliery industry is one of the most up-to-date of all industries as regards engineering generally (other than boiler plants), and there is not the slightest reason, therefore, why the boiler plant should not be as efficient as that of any other industry.

(To be continued.)

NEWALL EXTERNAL MICROMETERS.

Fig.7.

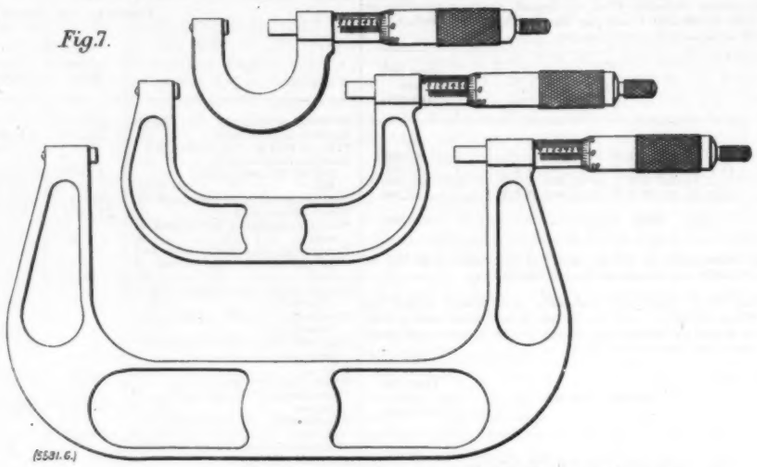
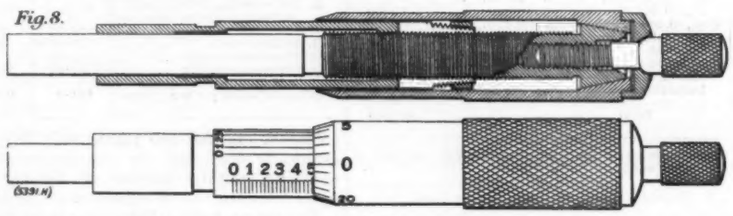


Fig.8.



NEWALL MEASURING MACHINES AND GAUGES.

THE Newall Engineering Company, whose factory at Walthamstow was, during the war, one of the National Gauge Factories, under the management of the Ministry of Munitions, has now been released from control, and the firm are therefore in a position to revert to the manufacture of their specialities.

On a recent visit to the works it was found that they had been considerably extended; this was necessary in the first place to the large volume of gauge and similar fine work which had to be produced to meet the requirements of the Ministry of Munitions and now fully engaged upon the increased output due to the firm having introduced new gauging appliances and established a special production department for the manufacture of gauges, jigs, fixtures and tools for the production of a specific article. In the case of the latter work the firm are prepared to design and manufacture the complete equipment of gauges, jigs and fixtures or to manufacture them to designs submitted to them, in either case they are willing to advise on the best method and apparatus necessary for securing economical production.

The illustrations on Plates V and VI give an idea of the workshops. Fig. 1, on Plate V, shows the screw-gauge section, and Fig. 2, on the same Plate, is a view of the chief test room, where every gauge and testing appliance is tested for accuracy and recorded before it

is passed to the stores. A general view of the machine shop is given in Fig. 3, Plate VI. From these views it will be seen that the shops are modern, they are well lighted and properly ventilated, and all details have been arranged to secure the sequence of operations and to make the conditions good for the skilled mechanics employed.

The firm are "manufacturing" gauges; in fact, all their standard products are made to stock and in batches of from 50 to 1,000 at a time, so that they can set up the machines for specific operations and keep control of the processes and inspections during the progress of the work through the shops. The advantages of working on such a system are well known in many engineering workshops, but it has a real significance upon output on fine work and where the accuracy of workmanship and finish is of primary importance.

The war gave the firm—due to the fact that the works were fully occupied upon standard designs of gauges, &c., required to execute orders to ensure the rapid and accurate production of all classes of munitions for Government Departments and contractors—an opportunity of examining their own designs and introducing improvements in their pre-war measuring appliances and gauges. The particulars of some of the modifications and additions are interesting, and indicate the policy of the company with respect to the supply of mechanical measuring and gauging apparatus for general engineering, the demands for which are sure to increase in the future.

The latest pattern of Newall measuring machine is shown in Fig. 4, Plate VI; the machine has already been described by us* but it is interesting to note that the first machine was produced in 1903 and was the practical corollary to the investigations undertaken by the firm prior to the issue in 1902 of their standard tables for their system of working to limit gauges. These tables have been extensively used by engineers to assist them in reaching the present-day standard of accuracy in workmanship, but a handy and accurate measuring machine in which reliance could be placed was a necessity if the gauges and other appliances required for such a system were to be produced at a reasonable cost and within the high and low limits laid down. Further, engineers required for their tool-rooms a measuring machine for checking their standard and workshop gauges.

The improvements introduced since the production of the first model of this machine have been continuous. The new devices and modifications which have been introduced to ensure accuracy and to increase the handiness of the machine are: (*a*) The compensator, (*b*) the adjustable vernier arm, (*c*) the new design of vee-block supports (shown on the measuring machine on the right of Fig. 2), and (*d*) a new and heavier form of bedplate (also seen on the right of Fig. 2).

The compensator (*a*) is shown clearly on the enlarged view of the headstock, Fig. 5, Plate VI, and it will be seen that on the extension of the measuring screw there is a cylindrical portion on which a square thread is cut. The thread has a flat top and is of the same pitch as the measuring screw, on the surface of the flat thread undulations are made to correspond with the ascertained small inaccuracies of pitch error in the measuring screw and by means of which a forward or backward movement is given through the roller and lever, to the arm on which the vernier is fixed.

The adjustable vernier arm is shown at B, Fig. 5, the object of this is to enable the operator who is making the measurements, to fix the position of the zero at the point convenient for ease of reading.

An improvement made possible through the firm having adopted spherically-ended measuring rods of uniform section for all lengths above 3 in., or 75 mm., is the new type of vee-block having a fixed height of centre. This modification enables the alteration in the setting of the headstock to be made rapidly as there is no necessity to alter the height of the vee-block for the varying sizes of rods. Further, the spherical-ended measuring rods eliminate a possible source of error as they give point contact, and thus obviate the inaccuracies due to imperfect flat faces or want of parallelism between the faces of the gauge.

In the latest type of measuring rods the fixed insulating handle has been omitted as it has been found to be unsatisfactory, it produced an unstable condition in the rod. The firm now supply plain measuring rods and a special lifting clip.

From a test recently carried out by the National Physical Laboratory we have abstracted the following results from the certificate of examination, carried out on a 12-in. Newall machine, and the figures show the high degree of accuracy secured in the latest machines.

Bed.—The working surfaces were found to be flat to within 0·0005 in.

Headstocks.—The measuring faces of the headstock were parallel to one another and to a plane perpendicular to the bed to within 0·00003 in.

The micrometer screw has 20 threads per inch, and as the drum is divided into 500 parts, each division represents 0·0001 in.; by means of the vernier the reading can be made to 0·00001 in. The micrometer has been tested for progressive error, and this has been found not to exceed 0·00002 in. over an inch run. The periodic error has been found to be within 0·00002 in.

The diagram, Fig. 6, Plate VI, is a reproduction of the National Physical Laboratory curve giving the calibration of the micrometer screw for this machine.

In Figs. 7 and 8, on page 104, are shown the latest patterns of external micrometers made by the firm. Three of the standard sizes of frame are shown in Fig. 7, but other sizes can be made to meet special requirements. From Fig. 8 it will be seen that the micrometer head is a separate unit. The design is liberal with large wearing surfaces, and the proportions ensure a rigid but light micrometer. The pitch of the screw is 0·025 in. and its inaccuracy is guaranteed to be within 0·0001 in. or 0·0025 mm. of true pitch.

For the measurement of holes and internal work the standard reference length rods shown in Fig. 9 should prove very useful. The standard set are suitable for measuring bores of from ¾ in. to 2 in., advancing by $\frac{1}{16}$ in. but the rods can be supplied to + or − limits. The rods are for convenience in use, slipped into the small holder shown in the front of the nest, Fig. 9. The design of this holder with a measuring rod in position is shown in Fig. 10. The rods are easily and quickly changed by turning the head through an arc of 25 deg. the rod is locked in position, and by a similar movement in the opposite direction it is released. The reference rods are of steel, spherically ended and ground to within a limit of inaccuracy of 0·0001 in. or 0·0025 mm.

In Fig. 11 are shown the firm's latest end-measuring blocks, the new blocks are of a more convenient section for bulk manufacture and due to the improved methods of manufacture are produced to a high degree of accuracy. The faces are guaranteed for truth and parallelism to 0·0001 in. or 0·0025 mm.

The firm have not materially altered their standard type of internal limit gauges except in respect to those of large size. They now make the ends of these in the form of disc flywheels (see Fig. 12); this shape has been adopted not only to reduce the weight of the gauge, which is marked, but to avoid the distortion during hardening which was sometimes a source of trouble in the older pattern.

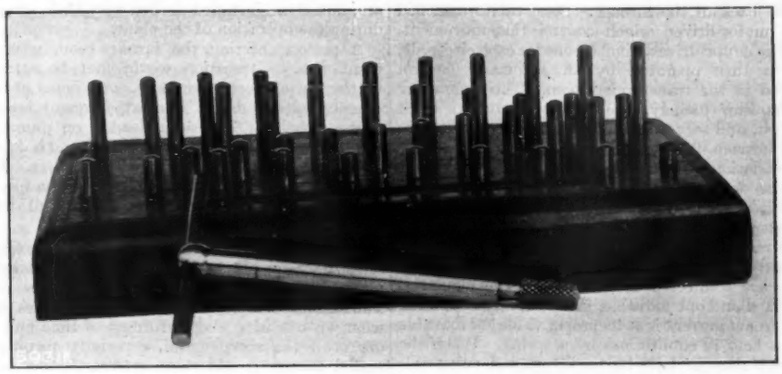


FIG. 9. STANDARD LENGTH REFERENCE RODS.

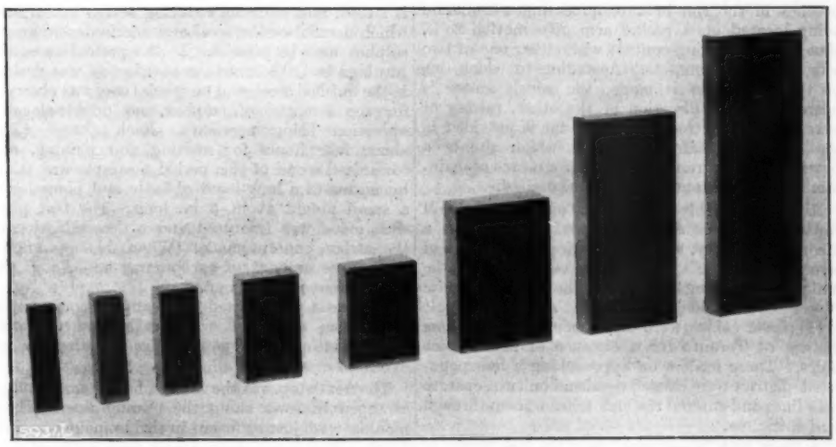
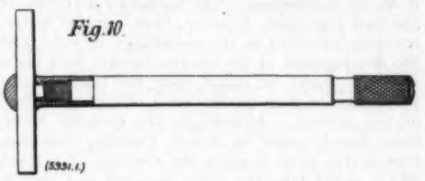


FIG. 11. END-MEASURING BLOCKS.



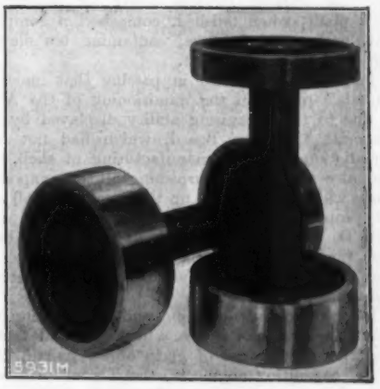


FIG. 12. INTERNAL LIMIT GAUGES.

* ENGINEERING, vol. lxxxi, page 79.

CANADA'S NATIONAL STEEL PLANT.

By W. F. Sutherland.

A romance of the scrap-heap fittingly describes the erection of a plant worth several million dollars in the short space of four months for the utilisation of material of low value, and its conversion into shell for the Allies. Canadian industries played a most important part in the winning of the war, as is attested by the fact that in the latter part of 1917, Canada was producing 55 per cent. of the shrapnel, 42 per cent. of the 4·5 in., 27 per cent. of the 6 in., 15 per cent. of the 8 in., and 16 per cent. of the 9·2 in. shell used by the British Armies.

It was early seen that this enormous output of the shell shops resulted in an ever-growing tonnage of scrap, mostly in the form of turnings, and it was a problem of no small difficulty to dispose of this material and to utilise it in such a way as to make it fit for further use. The industrial activities of the past few years, however, have resulted in far-reaching advances in the metallurgy of steel, and the development of the electric furnace to a point where it could be relied upon for the quantity production of high quality steel offered a solution of the problem. Accordingly the Imperial Munitions Board, under Sir Joseph Flavelle, chairman, took active steps towards the erection of a plant which would take the scrap material and turn it into the finished forgings ready for machining. This plant, when finished, comprised a complete unit with melting house, containing ten electric furnaces and a forge plant.

It may be remarked in passing that much of Canada's record in the munitioning of the Allies is due to the organising ability displayed by the Imperial Munitions Board, which had not only jurisdiction over the manufacturing of shell, but had also the task of furnishing all the component parts which go to make up the complete shell and its propellant. Existing plants could not cope with the task, so the Board built plants of its own, fuse plants, explosive plants, aeroplane factories, and lastly the British Forgings plant at Toronto, the subject of this article.

In the work of designing and constructing the plant, speed was, of course, a most essential factor, and the co-operation of Perin and Marshall, New York, consulting engineers, the Toronto Harbour Commissioners, the Hydro-Electric Power Commission of Ontario and the contractors, Messrs. Roger Miller and Sons, established a record which has rarely been surpassed, Mr. F. R. Miller being actively in charge of construction and operation. The design of the plant was carried out under the active supervision of Col. David Carnegie, ordnance adviser, and member of the Imperial Munitions Board. Ground was broken on February 1, 1917. Erection of the steel-work began in March, and the first furnace was put in operation June 16, just four months and 16 days from the start.

A spacious plant site was chosen, 130 acres in all, with seven miles of standard-gauge track, serving the many buildings and piles of shell turnings, the latter having at a distance much the same appearance as the stock piles of coal at the larger power stations. Cars of scrap entering the grounds were either unloaded on to these stock piles by locomotive cranes and lifting magnets or placed in the covered stock shed, 610 ft. long and 75 ft. wide, adjacent to the melting-house. This shed, or building, as it may more properly be termed, was provided as a winter storage, for turnings piled in the open would freeze to a solid rock-like mass very difficult to handle. The covered-in stock pile contained 12,000 tons of turnings at a time. Travelling cranes equipped with lifting magnets handle the turnings in the stock pile.

The melting-house or furnace-room, of which a view is given in Fig. 1, Plate VII, 610 ft. long and 75 ft. wide, contains 1,400 tons of structural steel, and has a lean-to 25 ft. wide between it and the covered stock pile. This lean-to houses the electrical equipment, and underneath serves for a bin storage for fluxes and other materials. The electric furnaces, ten in number and of the Héroult 6-ton type, are placed on a charging platform about 12 ft. above the main or casting floor. This charging floor, in addition to the furnaces, has space at either end for the relining of the furnace tops, and is on a level with platforms projecting into the covered-in turnings storage. Narrow-gauge dump-cars are loaded on these platforms by the lifting magnet, run over weight scales, and discharge the contents at the furnaces. Provision has been made in the charging platform for pouring the heat into the ladles and also for the picking up of ladles after they have been relined and pre-heated.

The Héroult furnace as used in the steel industry has three electrodes, for three-phase current, the arc being formed between these electrodes and the bath beneath. The 6-ton furnaces here used have electrodes of amorphous carbon 17 in. in diameter, and each length has a threaded hole in the end, so that by screwing in a carbon plug and screwing another length on top no waste carbon results from short ends. A view of one of these 6-ton furnaces is given in Fig. 2, Plate VII. Each electrode is held in a clamp, and is provided with means for moving up and down on a steel mast, as it is called, at the back of the furnace. Steel cables attached to a motor-driven winch control this movement, and the motor-driven winches, one for each electrode, are in turn operated by an automatic control located in the transformer room. This regulating mechanism, namely, the Thury regulator, is of interest, and serves to control the amount of power each furnace uses to a nicety, no matter how great the variation in resistance due to momentary short circuits or other causes. The current used is, of course, subject to the control of the operator on the charging floor.

Current transformers are installed in the high tension circuit of the furnace transformers, and these are connected to the coils of the regulator, one fixed and one movable, in such a way that when the furnace current is at its proper value the movable coil is held in equilibrium by a spring. When the current rises or falls below its normal value this equilibrium is destroyed and the coil and the rocking lever to which it is attached are swung one way or the other, engaging tappets which in turn release either one of two pawls. These pawls fall into notches in the rim of a reciprocating wheel, and being located on a rocker arm give motion to it, thus in turn making contact with either one of two sets of carbon contacts. According to which one of these contacts is made, the winch motor is operated in one direction or the other, raising or lowering the electrodes. A rheostat is provided in the current transformer circuit which shunts a portion of the current and provides a means of maintaining any constant current value desired.

A plant of this size, when operating to full capacity, requires as much electrical energy as a medium-sized city, and the electrical features are of some interest. To convey the current from the main transforming station of the Hydro-Electric Power Commission of Ontario, six 13,200 volt three-phase cables were laid through the business district of Toronto for a distance of about three miles. These feeders on approaching a less populated district were carried overhead on two separate pole-lines and entered the high-tension room through roof entrances.

A main high tension bus runs the full length of the high tension, switching and transformer room, and to this the incoming feeders are connected, first passing through 40,000 volt oil switches. Each feeder is protected with overload relays and lightning arresters. The transformers, ten in number, are of 1,500 k.v., a capacity each, and are located immediately behind the furnaces they serve, the leads passing through a wall into the melting house. Each transformer is also provided with a high-tension oil switch and protective apparatus. A view in one section of the transformer room is given in Fig. 4, Plate VIII.

Electric furnace plants at times are notorious for their poor power factor, but this plant, owing to careful design, proved to be an exception. This is true to such an extent that the power factor of the whole plant, including a heavy induction motor load, never went below 95 per cent. A motor generator set of 200 k.w. and having an a.c. synchronous motor helped in power factor correction.

In a plant of this size it is necessary to provide some means of central control from which switching operations can be carried on. This need was filled by the main control room centrally located between the two sections into which the main transformer room is divided. This control room projects out into the furnace room and gives the operators a clear view of the furnaces. It contains two switch-boards, one for the incoming feeders and the other for recording instruments for each furnace.

The furnaces are basic-lined up to the slag line. Magnesite bricks are laid on the bottom, and the walls built up of the same material to a little above the slag line. From this point up silica bricks are used, the roof also being formed to a domed shape of silica brick. Permanent expansion due to heating occurs in this refractory, and this is taken care of by laying up shingles in the courses. These char and burn out as the furnace is put on heat, and the brick expanding fills up the voids left. A basin-shaped bottom is made on the magnesite lining of grain magnesite mixed with basic slag. This sets solid when burned in with the electric arc, and those installed needed very little attention during the operation of the plant.

A person entering the furnace-room when the plant was in operation would first be attracted by the row of electric furnaces, some being charged, others melting down, and at frequent intervals others pouring. The scrap loaded on dump cars is rolled in from the loading platforms and is dumped on the charging floor beside the furnaces. From the pile thus formed it is charged into the furnaces by hand, and the necessary amount of fluxes, lime and fluorspar added as required.

The refining of steel in the open-hearth or electric furnace frequently includes the elimination of phosphorus or sulphur, and sometimes both. The elimination of the phosphorus takes place when an oxidising slag is formed of lime and iron ore or if the scrap metal, especially turnings, is rusted to any considerable extent, the ore is frequently omitted. The elimination of sulphur takes place mainly after the first slag is drawn off, and a new one formed of lime and ground coke. During this period silicon as ferro-silicon or carbon is added, and a strong reducing action takes place which deoxidises the steel and eliminates whatever sulphur may be present. In the present case, the turnings had the same composition as was desired in the finished steel, and no special care was observed for the removal of sulphur, no double-slagging operation being necessary. Each charge takes about four hours for melting and refining, and towards the end of this period a sample was taken by means of a long-handled ladle and poured into a small mould about 5 in. long. The test piece thus made was fractured and a determination of the carbon content made. When this was known the proper amount of carbon was added and the melt was ready to pour.

The furnace was tilted by means of motor-driven mechanism on the floor beneath, and the steel teemed into bottom-pour ladles handled by an overhead crane.

The next step was the filling of the ingot moulds, arranged in rows along the casting floor. These moulds were just sufficient in size to make one shell forging of the size desired and were made of cast iron with a hot-top or ring of core sand placed on top. The ingot moulds were smaller at the bottom than at the top, contrary to ordinary practice in the steel mill, and with the addition of the hot-top insured a perfectly sound ingot with very little waste. Piping or the creation of a cavity in the centre of the ingot due to the contraction of the steel has always been the steel maker's bete noir, and the making of steel for shell billets requires more than the usual amount of care.

Steel such as made at this plant had more than the usual tendency to form piping owing to its density and comparative freedom from occluded gases, but the Hadfield system of casting large end up and providing a head of molten metal to take up any shrinkage as it occurred produced uniformly good results. The function of the hot-top was to keep a certain amount of the steel fluid long after the greater portion of the ingot had cooled, this steel flowing into the ingot as needed.

Before filling, each mould is carefully cleaned by compressed air to remove any dirt and after filling, a

shovelful of earth or cinders from the floor being thrown on the steel to prevent its too rapid cooling. If the nozzle in the bottom of the ladle showed signs of stoppage an oxygen jet was brought into play and the partially solidified steel rapidly burned away.

Before the ingots had solidified metal tags were inserted in the molten top so that every heat might be readily identified. This heat number followed the billet, the forging, and finally the shell through every stage of manufacture. As soon as the ingots were cold they were removed from the ingot moulds. This was a comparatively easy task, as the slight shrinkage which takes place in the majority of cases allows them to readily drop out. Should they stick, a blow or two with a sledge readily removed them. The enormous output of the allied shell shops was only possible through the use of labour-saving devices wherever possible, and the use of conveyors toward this end is strikingly illustrated in this department of the plant under consideration. From the time the ingot left the melting house and was conveyed to the cutting and breaking shop until it left ready for the next operation, forging, no manual labour was necessary for its handling.

The ingots were carried from the melting house to the cutting and breaking shop by a conveyor which ran the full length of the latter. From this conveyor they were rolled on to a number of tables where they were stamped with the heat number. Pneumatic hoists then picked them off the table and placed them in the cutting-off machines which cut a deep groove partially through them just below the crop end or scrap portion. Seventeen machines, when the plant was in operation, were required to handle the output of the melting house. A view in the grooving shop is given in Fig. 5, Plate VIII.

After grooving, the ingots were transferred to another conveyor and carried to the breaking hammer, a "steam" hammer run by compressed air. This hammer, which is shown in Fig. 3, Plate VII, broke off the crop end, which fell to one side down a chute and into a conveyor from which it eventually found its way into the furnaces again. The shell billet rolled the other way on to another conveyor and went to the inspection tables. Here it was examined for flaws, piping and other mechanical defects.

The inspection of shell steel, as many plants found to their sorrow, was an exceedingly rigorous operation, and the care taken did not stop here with the mere mechanical tests, but one crop end in each melt was painted red as a distinguishing mark. When this end was broken off it was rescued from the remainder of the scrap, and drillings were taken for analysis.

The forge shop, located conveniently near the shop in which the last operation was performed, is a spacious building, of which a view is given in Fig. 6, Plate VIII, in which the operations connected with the production of the finished forging from the billets were carried on. The high-explosive shell in the smaller sizes, as is well known, has comparatively thick walls and a closed base, the loading being done from the nose, where the fuse is afterwards screwed on. The various operations connected with the production of the shell forging have to do with the piercing of the billet or making the hole, and at the same time drawing the billet out to the proper length.

Various operations with which we are not concerned were next done in the machine shop, such as machining and nosing-in, which give the shell its finished form. It might be mentioned here, however, that a special precaution was taken to ensure absolute gas-tightedness of the base. The base was recessed for a base plug or plate of steel, which was inserted and securely riveted in. This feature gave additional security and prevented the premature deterioration of the shell in the gun if by any chance a flaw or trace of piping remained.

To return to the forging operation. The billets as they were received from the cutting and breaking department weighed about 158 lbs. and measured about 6 in. average diameter for a 6 in. shell. Each lot as it was received was piled at the back of the heating furnaces, care being taken to keep all billets belonging to the same heat number together, and separate from other lots.

The furnaces, of which there are 13, are of the continuous type; that is, they take the cold billet in at one end and deliver it at the proper temperature at the front. Oil firing was used, and very little attention was required to maintain a uniform temperature. As the billets passed through the furnace they turned, reached the proper temperature, and were ready for piercing as they came to the front. Here they were picked up as required by means of tongs on overhead runways and swung into the forging presses. Six 500-ton presses were required, and to serve these presses ten 200-gallon electrically-driven pumps were installed in a separate building. The billet, now at the proper forging temperature, was dropped into the die and a centering ring placed on it to guide the punch. The piercing and drawing of the 6 in. shell forging were done in one operation, for as the punch descended it caused an upward extension of the metal out of the die. On the return stroke the punch was withdrawn and the forging forced out of the die by a kicker. It was then placed on another conveyor and removed to the cooling beds.

The various heats were still kept separate, and when the forgings were sufficiently cooled they were again inspected, stamped with the heat number, and one picked at random for sawing up into test pieces. This completed the operations on the forging, and it was then ready for the shell shop, except when it did not come up to requirements as regards physical properties, in which case it was given a further heat treatment or normalising process, as it was termed. As was the experience at shell factories elsewhere, it was found that the distance apart of the shell forgings when cooling had a marked effect on the hardness of the forging. The heat was dissipated rapidly or slowly according as the forgings were spaced apart or more closely together, and it was often possible to control desired characteristics by this means alone.

An enormous output of forgings was reached day in and day out at this plant, no less than 8,000 6 in. shell forgings being produced on three presses per day of 24 hours at various times. This daily output would require a good-sized train of 20 cars for its removal.

THE NATIONAL PHYSICAL LABORATORY.

(*Concluded from page* 91.)

Thermometer-Testing (Messrs. W. F. Higgins, B.Sc., W. Hugo, and A. Cooper).—All clinical thermometers have now to be tested at the National Physical Laboratory, and the provisions made for this purpose enable Mr. Higgins and his staff of a hundred women to deal with 30,000 thermometers a week. One more room has been taken up in Bushy House for the work, and another room for four more testing baths and a large work-room have been found in the administrative building. The new baths are made by Messrs. Baird & Tatlock, to the design of the Laboratory which itself made the older baths and has slightly improved the switching arrangements for the bath heating (by electric mats). In the baths the thermometers are held by the spring clips (of phosphor bronze) of the cages; they are afterwards waxed, engraved, etched with hydrofluoric acid, and blacked; the blacking is simply rubbed in with the aid of tissue paper. The pantograph of the Laboratory, which scratches the N.P.L. mark into the tested thermometer, has been provided with a ball pivot, and can thus be worked without exposing the links to any strain. These montonous operations are carried on in shifts of two hours' length. For the standardisation of thermometers at higher temperatures, in the vapours of naphthalene, diphenylamine and other substances serviceable for constant temperature baths, some very simple apparatus have been set up. Each apparatus consists of a piece of vertical 1½ in. gas piping, about 5 ft. high, closed at the top, but communicating with the outer atmosphere through a prolongation of another piece of gas piping of smaller diameter. Underneath the pipe, which is heavily lagged, is a gas burner to vaporise the liquid or solid material; when the material is liquid, a grid is fixed above it to prevent its splashing. The thermometer is suspended by means of a brass boss or collar; these bosses are made in sizes increasing by 1 mm. in diameter; the thermometer passes loosely through the boss and is held in position by a rubber ring slipped over the thermometer. With this simple method of suspension the thermometer can easily be fixed and removed, whilst the fitting into stoppers and the removal therefrom is a troublesome business. Most of the thermometer-glass tubing is manufactured by Messrs. H. Powell and is distinguished from other tubing by a blue streak.

Radium and X-Ray Work (Dr. E. A. Owen, M.A.).—The chief radium work has been the testing of samples of radium, obtained from different sources, for the Government. The samples may range in weight from about 30 milligrams upward, and the results of the tests are expressed in terms of radium bromide. The radium standard also consists of about 30 mg. of the bromide which is kept in a fine glass tube enclosed in a screwed-down, lead-lined steel tube. The practical methods of conducting these tests rely upon the determination of the γ-ray activity of the radium salt in a sealed tube which will reach a minimum in about two months; that time should hence be allowed for an accurate test. The comparison of the γ-ray activity can be affected with the aid of an electroscope composed of a lead plate 3 mm. in thickness or completely surrounded by a lead cover of this thickness which will stop all β-rays (as well as α-rays) so that the radioactivity observed is entirely due to the more penetrating γ-rays. The intensity of the radiation is estimated from the rate of movement of the gold-leaf electroscope, and this movement, the rate of leakage of the charge given to the electroscope, depends upon the ionisation produced in the ionisation chamber by the rays from the radium salt which is held at a certain distance from the chamber. When the sample and the radium standard are of about the same activity, the comparison can be effected within an accuracy of ½ per cent.; when the quantities compared differ considerably, the saturation of the ionisation may not be complete in the case of the smaller sample, and the result is unreliable. This defect of the direct comparison method is avoided by the balance method of Rutherford and Chadwick, which Dr. Owen has adopted.

This method requires the use of an additional constant source of ionisation, a vessel containing uranium oxide. The γ-rays from the radium standard enter the ionisation chamber A, the current of which is balanced by the opposing ionisation current from the uranium vessel B; the standard is now removed, and the sample brought up to A from the distance until balance is once more obtained. The estimate is based upon the distance. This approach is effected on a photometer bench, and the observer sits in front of the bench, 4 metres long, and slides the carrier for the sample which is attached to a wire until balance is established. Dr. Owen's arrangements much facilitate the observation; the electrometer light-spot is brought on to a scale near the handle, by which the wire is moved over its pulleys, and the earthing key of the electrometer is operated from the same place. The vessel A is a lead cylinder, resting on its circumference, and having a length (height) of 10 cm.; the diameter is about 15 cm., the wall thickness 3 cm., and the cover, through which the γ-rays have to pass, has generally a thickness of 1 cm., but that thickness can be varied between the ranges 1 mm. and 2 cm. The electrode inside the vessel A is an aluminium disc. The uranium vessel B is a brass cylinder (surrounded by 3 cm. of lead), at the bottom of which lies a plate covered with uranium oxide; above this plate is an iris diaphragm, and further up the horizontal disc electrode. Both these electrodes are joined to the electrometer, but the two vessels are kept as far apart as possible, the distance being more than 3 m., at Teddington, and the long wire connecting A and the electrometer is encased in a stout lead tube (3 m. long), in which a fair vacuum of 1 or 2 cm. is maintained, lest the air surrounding the wire should be ionised by some external radiation.

The work on X-ray examination of the clays*

* ENGINEERING, June 6, 1919, page 726.

used for making glass-melting pots, to which Dr. Rosenhain referred in his discussion of "Pot Attack," is being continued in Dr. Owen's laboratory.

Optics Division. (Messrs. T. Smith, J. Guild, J. S. Anderson, W. J. Boxall, W. J. Stockwell, A. G. Williams, Miss A. B. Dale).—The sextant testing, of which Mr. Boxall has entire charge, and the testing of binoculars and telescopes (Messrs. Stockwell and Williams) do not claim so much time and patient work now, but the general testing work of optical glass, mirrors, prisms, and lenses, remains very heavy. We briefly notice some of the devices adopted. Pointolite lamps have replaced the Nernst lamps as sources of light. For the simple homogeneity test of mirrors an arc lamp (carbons at right angles) is sufficient; the light of the mirror is reflected on to a screen on which any scratches, polish marks, striæ, &c., can be seen; the apparatus can also be arranged for showing the homogeneity of glass plates by transmitted light, when a peculiar marbled effect may be observed. The flatness test is made with the aid of a quartz optical flat which is placed on the top of the plate to be tested. Above the two is the cylindrical box down which the monochromatic light of a quartz mercury lamp is sent by a mirror. The observer looking through an eye-piece across the box sees a number of fringe lines which will be straight and parallel to one another if the plate be perfectly plane in the direction of the fringe; when the plate is turned in its plane, another system of fringes is seen, and in this way the surface of the plate is mapped out. To facilitate this work, a scale is marked on the quartz plate. The Twyman interferometer of Messrs. A. Hilger, a kind of Michelson apparatus, serves for the examination of prisms and lenses and of optical combinations which are required to receive, and also to transmit, a beam with plane wave-front and to impart spherical wave-fronts to beams received with plane wave-fronts. When a prism is to be tested for homogeneity and want of planeness, a parallel beam of mercury light (collimated) falls on a plane-parallel plate (which is silvered at the back) and is split, the greater portion of the light being reflected; the transmitted beam passes through the prisms under test on to a mirror and back through the prism; the reflected beam goes to another mirror and back. The recombined beams are viewed through a hole in a diaphragm, and an image of this hole is seen surrounded by a system of rings, the distortion of which represents twice the distortion which the prism has impressed upon the wave-front. This distortion can be removed by local grinding of the prism faces at the respective points hit by the rays. In testing blocks of glass for strains, the specimen is placed between Nicols, and the image examined on a ground glass screen. Use is also made of a Bellingham-Stanley polarimeter and a Schmidt-Hænsch spectrophotometer, but in these latter instruments the light-absorption is large.

Curvature measurements are effected by three methods. Very flat lenses are examined with a modification of the Newton-ring method. The green mercury line is used, and the light reflected down a vertical tube falls on an optical flat and the lens underneath it; this arrangement avoids the complication of the observations by the magnification due to the lens, which would enter if the lens were placed on top of the flat as is usual. For sharper curves the Guild spherometer is used, which we illustrated last year.* Curvatures of very short radii, down to 3 mm., are examined by measuring an image in terms of an eye-piece scale plotted against a surface of known curvature. Angle measurements are made with the aid of goniometers, or, in the case of prisms of 60 deg. particularly, with the aid of two telescopes and a collimator to be arranged symmetrically about a small table, on which the prism is placed. When one telescope has been adjusted with the aid of its micrometer for the wire cross with respect to one face of the prism, the prism is turned with its table until the second face appears in the same direction; the observations are repeated, and averages are taken of these and the other measurements, of which the instrument admits, which generally agree within seconds of arc. The Pulfrich refractometer and the modification this instrument is undergoing at Teddington were referred to last year. When working with monochromatic light a wide slit and a vertical cross line are preferred to the narrow slit and horizontal line, and the violet hydrogen line is filtered through cobalt glass to get rid of the satellites.

We mention finally a modification of the method for testing camera-shutters for speed. The source of light is a pointolite lamp; an image of the point source is thrown, by a rotating mirror, through the shutter on to a photographic film. The mirror belongs to a galvanometer which is in circuit with a battery of about 5 volts and a tuning fork, so that the image of the source describes a sine-curve of light; this curve is received on a film, which is wound on a revolving drum. The number of fork vibrations being known, the number of waves on the film gives the speed of the shutter action. In the old arrangement the trace was received on a dropping photographic plate, and part of the trace might be lost by falling beyond the plate; on the film drum the number of waves can be counted, even if the trace should fall on the line where the film edges join.

* ENGINEERING, August 16, 1918, page 178.

SOME DEVELOPMENTS IN AIRCRAFT DESIGN AND APPLICATION DURING THE WAR.*

By the Right Hon. Lord WEIR OF EASTWOOD, P.C., Honorary Fellow.

(*Concluded from page* 99.)

PART III.—PROGRESS IN ENGINE DESIGN.

Before 1914 it may be said that aero engine design had merely reached the stage of sufficient reduction of weight/power ratio to enable aeroplanes to fly. Beyond this, practically no special adaptation to aeroplane requirements had been attempted. The development of the aerial arm in the war, however, speedily emphasised the importance of other factors. The extension of the range of operations and the losses of machines, due to engine failure, raised insistent demands for greater reliability, whilst the necessity for easier maintenance called for engines of greater all-round accessibility.

The rapid progress of flying skill and the adoption of aerial acrobatics in fighting created a demand for engines of short length and quick controllability.

The desirability of carrying out reconnaissance untroubled by enemy attack or anti-aircraft fire focussed attention on the necessity of increasing the ceiling or maximum height of operation. Coping with this most important requirement again produced an improvement of the weight/power ratio, and the ceiling of approximately 7,000 ft. in 1914 was increased to nearly 30,000 ft. by the beginning of 1919. It must be remembered also that the diminished density at great height decreases the amount of oxygen taken into the engine, and therefore the power which the engine can deliver. At 15,000 ft., for instance, a 300-h.p. engine can only deliver about 200 h.p.

The extension of bombing activities at long ranges emphasised the importance of the study of the fuel consumption which, for a flight of 6 hours, amounts to a large weight per horse-power. The question of the thermal efficiency had therefore to be studied in conjunction with the weight-power ratio, so that engine speeds increased whilst the aerodynamic requirements of the machine demanded reduced propeller speeds.

Long before the end of the war the power requirements of some aeroplanes and seaplanes had far outstripped the possibilities of any one engine, so that machines possessing two, three, four, or even more engines, were in service or being built.

An important factor affecting aero engine development is the time which is required to produce a new design. Generally about eighteen months would have to elapse between the commencement of the design and a useful flow of reliable production engines. During most of this period no useful practical experience can be obtained as to the qualities or defects of the new design, and by the time bulk experience of its behaviour in service is available, it is necessary to supersede it by another more advanced type. Less than half the time is required for the development and trial of an aeroplane design, so that the aeroplane is generally well ahead of the engine for which it is designed.

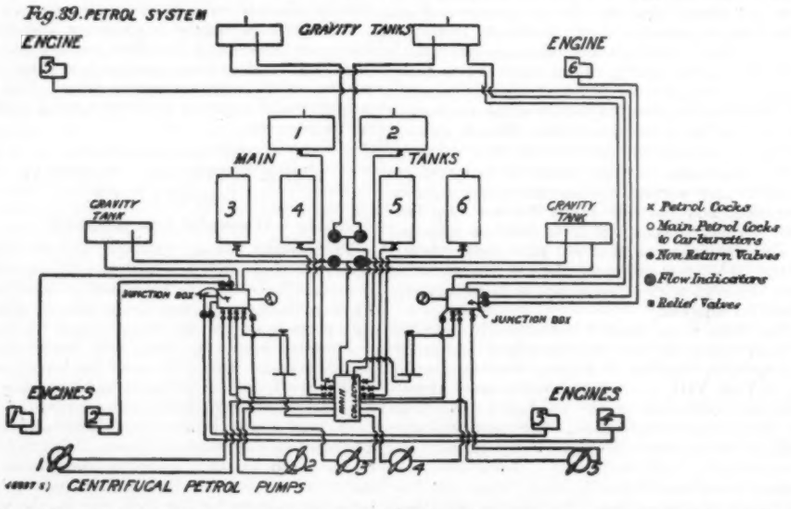
In 1914 our aircraft engine position was by no means satisfactory, and we depended for a large proportion of our supplies on other countries, principally on France, whose Gnome and Renault engines were pre-eminent. Great efforts were immediately made to extend our sources of design and supply, and by the end of the war British engines had gained foremost place in design, and were well up to requirements as regards supply.

Many of the earlier designs were considerably influenced by previous automobile engine practice, but a wide divergence of design and detail soon took place due to the entirely different nature of the conditions to be faced. In automobile practice silence and good carburation over a wide variation of speeds and loads were the most important features, whereas those points are of small importance for an aircraft engine. The task of the aero-engine designer was still further complicated by the fact that the order of importance of the various features of the engine is different according to the class of machine for which the engine is being designed. Certain entirely novel conditions had to be met and their attendant difficulties overcome. For example, an aero engine must have the ability to function in practically any position and, for a time at least, when completely inverted. This requirement has had a far-reaching effect on the lubrication system of aero engines, as it practically precludes the carrying of oil in the crank-case.

The shape of the engine is a matter requiring careful consideration for aircraft, as head-resistance, accessibility and small moment of inertia are all features of considerable importance dependant on the shape. The wide ranges of temperature and pressure through which an aeroplane may pass affect the carburation, the cooling system, the lubrication system, and even the ignition, to a very serious degree. An aeroplane may undergo a very rapid change of as much as 75 deg. F. in temperature, combined with the maximum difference in moisture content of the air. With water-cooled engines, therefore, it has been found necessary to put a thermometer in the circuit and fit the radiator with blinds operated by the pilot, and even with such accessories the maintenance of the water at a constant temperature has often been a matter of great difficulty, and has thrown a heavy responsibility upon the pilot. At the same time evaporation losses must be reduced to a minimum, as the amount of water lost on long journeys is an important feature, so much so that it is true to say that the Atlantic could not be flown to-day with any of the water-cooling systems that were deemed sufficient at the outbreak of war.

The intense vibration due to the conditions of high speed and lack of rigid support under which aero engines must work impose new and severe conditions mechanically on every part. The violent and varying slip stream from the propeller also imposes a new problem as regards carburettor intake conditions, where again the seriousness of fire risk has to be taken into account and avoided. Probably no detail of the whole engine process has received more expert and prolonged attention than the ignition, and much of the increased reliability and efficiency of the modern engine undoubtedly results from this work.

The very severe centrifugal and inertia effects which are experienced in aerial fighting, coupled with the



* Paper read before the North-East Coast Institution of Engineers and Shipbuilders, July 10, 1919.

necessity under such conditions of immediate response to the throttle, have necessitated careful design of the petrol supply system to ensure a constant and adequate supply of fuel.

In addition, the length and ramifications of the fuel system have increased considerably with the growth in the size of machines and in the number of engines. Fig. 39 shows a typical lay-out of petrol system for a large modern multi-engined machine. The main tanks are numbered 1, 2, 3, 4, 5 and 6, and have a combined capacity of 1,800 gallons of petrol. These six tanks feed by gravity to the main collector which is situated in the engineer's cabin. In each of the pipes between the collector and tanks is fitted a non-return valve to obviate any possibility of the petrol running from the top tanks into the bottom as these six tanks are not all on the same level.

From this collecting box the petrol is lifted by five centrifugal pumps, which are shown below, into the junction boxes, which feed the engines. These centrifugal petrol pumps are driven by airscrews which are placed in the slip stream of the propellers in order that the petrol shall be pumped up whilst the machine is stationary. If these pumps should fail to act the petrol can still be lifted to the junction boxes by the hand pumps shown one on each side just above the collector.

The two distributors or junction boxes feed the engines; that on the left feeding the four bottom engines, whilst the other supplies the two top engines. As the petrol supplied to these distributors is more than that used by the engines, the extra amount passes up to four small gravity tanks which will be seen in the illustration and which are situated in the planes. These hold about 15 gallons each. As the excess of petrol continues the gravity tanks overflow through return pipes into the main collector. In these pipes flow indicators are fitted in order that the engineer may see that the system is properly working. After the main tanks are empty and no more petrol is supplied to the distributors the petrol flows from the gravity tanks into the junction boxes which ensure a further 60 gallons. The two junction boxes are fitted with indicators to show the pressure or head of petrol supplied. They are also fitted with relief valves discharging back into the collector. The collector is also fitted with a large filter, through which all the petrol passes on its way to the engine.

A great deal of progress has been achieved in the general arrangement of the engine and its cylinders so that the most effective use is made of all the material. With cylinders in line the deadweight loss per horse-power will rapidly decrease after the first cylinder, but after about four cylinders the economy to be gained by adding more cylinders practically ceases owing to the increased size of crankshaft and bearings required to resist torsion. This naturally leads to grouping the cylinders in two rows in V form working on a common crankshaft, with two connecting rods to each crank-pin. Many such engines have been made with two rows of either four or six cylinders each. Further extension of this principle has enabled Messrs. Napier to produce a twelve-cylinder engine of 450 h.p., with three rows of four cylinders (three connecting rods to each crank-pin), and weighing only 1·86 lb. per horse-power dry weight.

In addition to placing cylinders in line, designers have from the earliest days of aero engines been attracted by the scheme for mounting all the cylinders radially around a common crank. By this arrangement the length of crankshaft and crank-case is, of course, reduced to a minimum, and there have been engines with three, five, six, seven, nine, ten, and fourteen cylinders in one or two planes. Of this type the Cosmos Company have produced a 450-h.p. nine-cylinder air-cooled radial engine, which weighs only 1·47 lb. per horse-power, or less than one-third the weights of similar type French engines of 1914–15.

Radial engines include those of the rotary air-cooled type, and progress in this type can be best indicated by taking the French 80-h.p. Gnome of 3·26 lb. per brake horse-power, and comparing it with the British Bentley engine of 230 h.p., weighing only 2·165 lb. per horse-power, a reduction of about 30 per cent. in spite of the tremendous increase in the centrifugal load. With

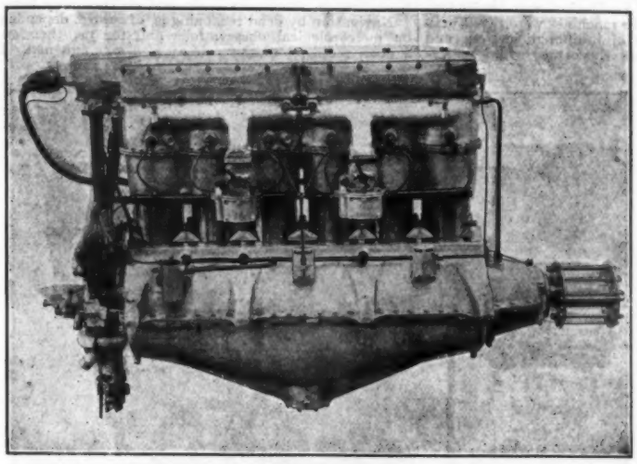


FIG. 40. 230 "PUMA" (SIDDELEY).

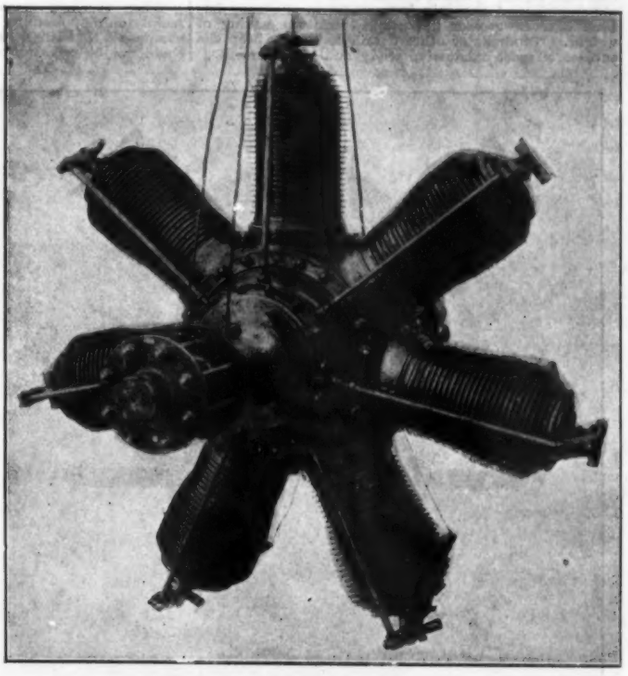


FIG. 41. 80 GNOME.

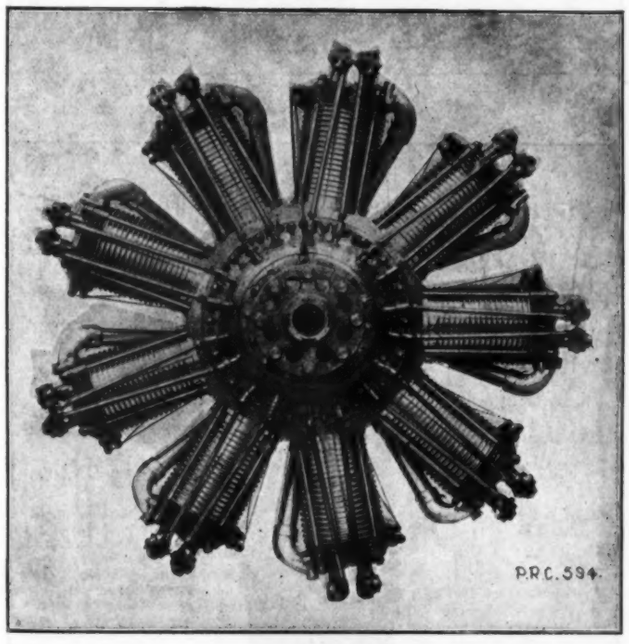


FIG. 42. BENTLEY ROTARY.

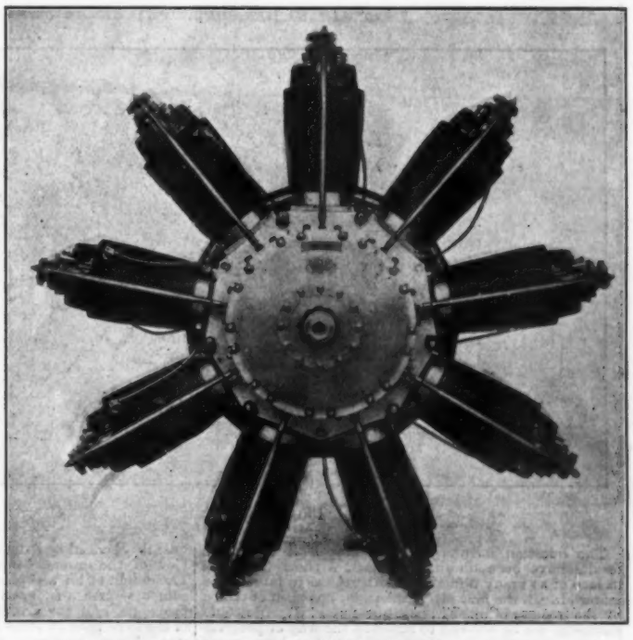


FIG. 43. A.B.C. DRAGONFLY.

radial engines of large size, however, the increased head resistance is a serious objection, and it is not likely that this method of arrangement can be extended indefinitely as regards size.

A saving in weight and great improvement in mechanical efficiency have been obtained by eliminating the valve tappet rods and substituting overhead camshafts operating directly on the valves. Further economies have been effected by the employment of aluminium for the cylinders fitted with either steel or cast-iron liners. Pistons are now universally made of aluminium, and the gain in mechanical efficiency has been of even greater importance than the saving of weight. Hundreds of other details have also been the subject of most exhaustive study and improvement.

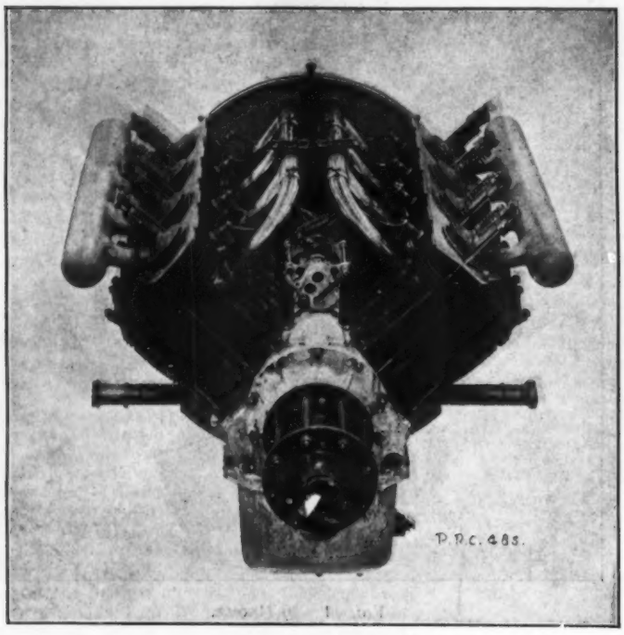


FIG. 44. 80 RENAULT.

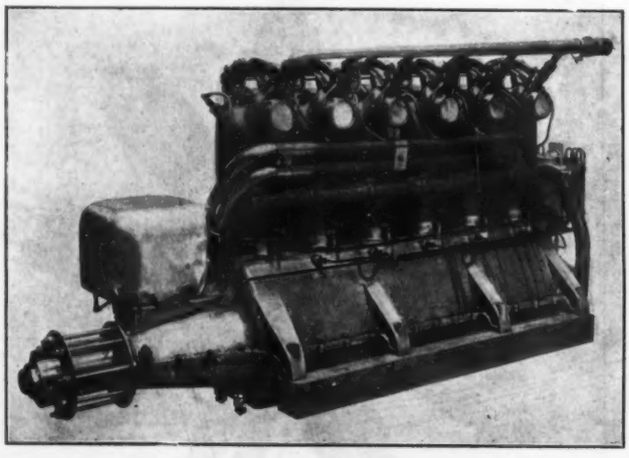


FIG. 46. 160 BEARDMORE.

The question naturally arises, how is it that such results have been obtained in such a short time and in face of so many difficulties with regard to labour and material. In the first place, the result has been obtained by the free use of money; the question of expense could naturally not be allowed to stand in the way of progress in this all-important matter. Money has been spent on research, on steels and other materials, processes of manufacture, inspection organisations, &c., and the amount of scrapping of material and parts not up to standard has been on a scale that no commercial firm could adopt, and live. The greatest credit is due to the steel manufacturers for the manner in which they collaborated with the Government on the evolution of special steels and the preparation of standardised specifications. The table on page 111 gives the principal particulars of some of the leading engines of to-day.

PART IV.—NAVIGATION AND METEOROLOGY.

Although great strides have been made during the last year in the development of scientific navigation the weather still remains the dominating factor in all flying operations.

During the war the whole of our aerial work was controlled by weather conditions, although in the later phases a vast amount of successful operations were carried out in weather which, before the war, would have been considered far too bad to allow of any flying at all. The problem of flying in anything like a thick fog or ground mist remains unsolved, and if flying in this country is to be a real commercial proposition much solid research in this direction will be necessary.

When the war started, navigation was dependent mainly on map reading. Our machines were fitted with compasses, but these were of indifferent design, and could not be relied on unless the course could be frequently checked by a direct view of the ground below. The design of an aeroplane compass presents special problems, and the errors involved in using a compass of the type used on ships had not been realised before the war. These problems were successfully investigated by the late Keith Lucas, who evolved a satisfactory aeroplane compass. This compass and subsequent types based on its design were standardised. Even with the improved compass, navigation in unfavourable weather conditions still presents great difficulties.

The very great advantages, especially in long-distance bombing operations, of being able to fly for considerable distances through clouds were clearly realised, and a special research was undertaken to make this a practical proposition. Excellent results were obtained, chiefly due to the introduction of an instrument called the turn indicator. When flying in a cloud or a fog bank the pilot loses all sense of direction, but this instrument used in conjunction with the compass enables him to steer a straight course, even in these circumstances.

At the time of the signing of the armistice we were training pilots in large numbers in the use of these instruments, and there is no doubt that the Germans would have had some unpleasant surprises a few months afterwards, when formations of bombing aeroplanes would have suddenly emerged from the clouds over the objectives when the inhabitants below might reasonably have considered themselves safe. Before any attempt could be made to attack them our aeroplanes would have been back in the clouds again and on their way home.

Navigation by dead reckoning is, of course, dependent on meteorological observations and for us, therefore, a good meteorological service was a *sine qua non*. It must be remembered that on the Western Front we had always this important disadvantage, that the prevailing wind was blowing from west to east, thus tending to drift our aeroplanes away from our lines and reduce their chances of getting back when in difficulty. In spite of this the vast majority of air fighting took place well on the German side of the lines, and, even allowing for the German raids over England, the amount of reconnaissance and bombing we carried out over German occupied territory was far greater than that attempted by them on our side of the line. Although, of course, the credit for this is mainly due to the magnificent spirit of our *personnel*, the effectiveness of our meteorological service had some effect in establishing our ascendancy.

A few words may be added about the use of directional wireless for navigation. The Germans used this method for directing their Zeppelins in the raid over England, but

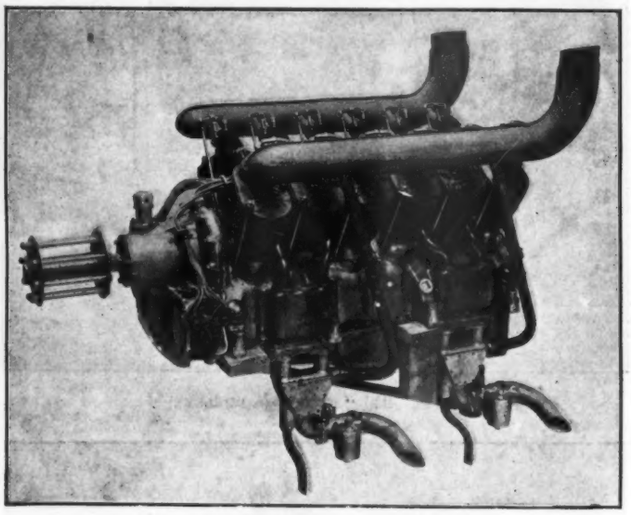


FIG. 45. 140 R.A.F. 4A.

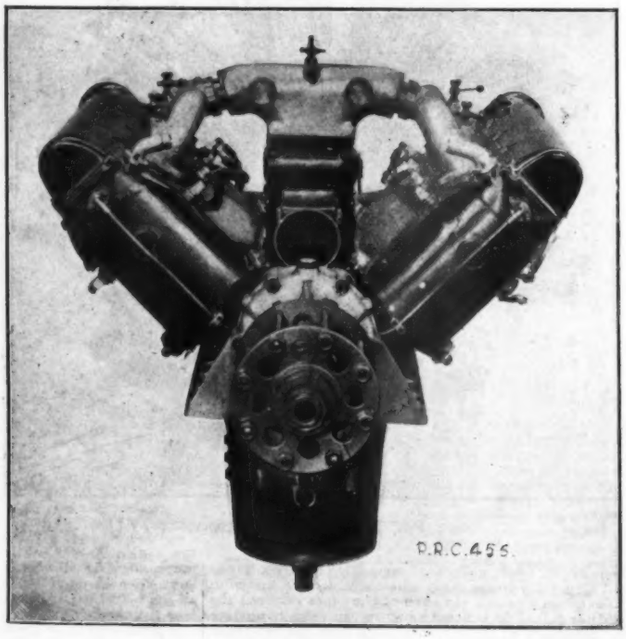


FIG. 47. HISPANO-SUIZA.

the system they used involved the sending out of frequent signals from the airship to be picked up by the German wireless stations. The latter would then send out signals to the airship indicating its exact position. This system had the great disadvantage that we also could pick up the airship's signals and thus locate its position. So we always knew where they were coming from, and arranged our defence accordingly. Our own system was for the aircraft to carry the directional coils, and by picking up signals from home stations, to locate its own position. Our apparatus was only perfected late in the war, but we counted on using it effectively in the projected raids over Berlin, to which I have already referred. With further research and development there are good prospects that directional wireless will be of the greatest value in the long distance navigation of commercial aircraft in the future.

Future Developments.—Any reference to the future of aviation must necessarily be very brief and purely general in character. The rapid and quite abnormal growth in the technique and application of aircraft under the stress and artificial conditions of war-time must now give place to the more sober rate of development of peace time.

Our peace-time Royal Air Force, as I visualise it, will become a relatively small organisation of remarkable efficiency with the highest ideals and with the keenest *esprit de corps*. Its *materiel* should represent the last word in technical progress such as can only be achieved by considerable expenditure. Quality must be the keynote of its policy not only in *materiel* but also in *personnel*.

An outbreak of war must see us with the very best designs of engine and aircraft, tried and tested, and with a manufacturing nucleus on which war production may be readily expanded.

In regard to civil aviation, one is naturally unhappy at the necessity of adopting the prophetic role, but one factor is clear and definite. Our Government must accept the heritage of war experience, and by action, support and sympathy, encourage and develop its translation into the new channels of peace requirements.

The more immediate problems of international and domestic aerial legislation have now been provisionally solved by the International Aerial Convention and by the Civil Aviation Act, and it is very gratifying that in both these directions Great Britain has taken the lead and shown the way.

In another direction much remains to be carried out quickly. Our great mercantile marine in all its technical perfection would avail but little without our harbours, docks, lighthouses, charts, and navigational instruments. We possess fleets of aircraft of reliability and of great performance possibility, but our navigational facilities are still almost non-existent, and herein lies one of the main fields of action of our new Department of Civil Aviation.

In all considerations for the future of Civil aviation, the two qualities of outstanding merit appertainable to the new form of transport are speed and independence of action as against land transport requiring roads or rails. These constitute the only assets for any commercial future. Speed in transport is associated with high cost, and speed will always command a high value. Early action should be taken in regard to a few main routes, especially in countries with equable weather conditions, and especially in new countries, backward in rail development.

To such main routes would be Egypt to India, and Egypt to South Africa.

Another early development with immediate possibilities will be the use of large flying boats for inter-island and coastal traffic, for example, in the West Indies

PARTICULARS OF REPRESENTATIVE BRITISH AERO ENGINES OF EACH TYPE. MAY, 1919.

Type.	Method of Cooling.	No. of Cylinder.	Bore m/m.	Stroke m/m.	Compression Ratio—to 1.	Piston Speed ft. per minute.	B.H.P.		Speed.		M.E.P.		Normal Propeller Speed.	Dry Weight in Lbs.	Lb. per H.P.		Petrol lbs. per Normal H.P. Hour.	Oil lbs. per Normal H.P. Hour.
							Normal.	Max.	Normal. R.P.M.	Max. R.P.M.	Normal.	Max.			Dry.	Wet.		
Bentley, Rotary 2 (Fig. 42) ..	Air ..	9	140·00	180·00	5·26	1,536·0	230	284	1,300	1,360	92·0	—	1,300	498	2·165	—	0·63	0·088
A.B.C., Fixed Radial, "Dragonfly" (Fig. 43)	Air ..	9	139·7	165·09	4·42	1,787·5	320	350	1,650	1,750	110·0	—	1,650	635	1·98	—	0·585	0·028
Straight Six, Siddeley, "Puma" (Fig. 40)	Water ..	6	145·00	190·00	5·00	1,558·0	250	266	1,400	1,600	115·0	123·0	1,400	645	2·58	—	0·6	0·062
2 rows of 4 V. at 90 deg. Sunbeam, "Arab"	Water ..	8	120·00	130·00	5·3	1,707·0	212	220	2,000	2,100	112·0	—	1,200	550	2·6	3·24	0·486	0·039
2 rows of 6 V. at 60 deg. Rolls-Royce, "Eagle" 8 (Fig. 49)	Water ..	12	114·29	165·09	5·3	1,950·0	350	368	1,800	1,900	127·2	131·4 at 1,500	1,080	926	2·58	3·23	0·5	0·025
2 rows of 6 V. at 60 deg. Galloway, "Atlantic" (Fig. 50)	Water ..	12	145·00	190·00	5·4	1,872·0	550	575	1,500	1,600	126·3	—	1,500	1,150	2·09	2·74	0·504	0·045
2 rows of 6 V. at 60 deg. Rolls-Royce, "Condor"	Water ..	12	139·69	190·5	5·1	2,187·5	610	656	1,750	2,000	129·0	129·4	971	1,350	2·21	2·86	0·495	0·0225
3 rows of 4 V. at 60 deg. Napier, "Lion" (Fig. 48)	Water ..	12	139·69	190·17	5·55	1,708·0	450	468	2,000	2,100	122·0	126·0	840	1,318	1·86	2·51	0·495	0·0225

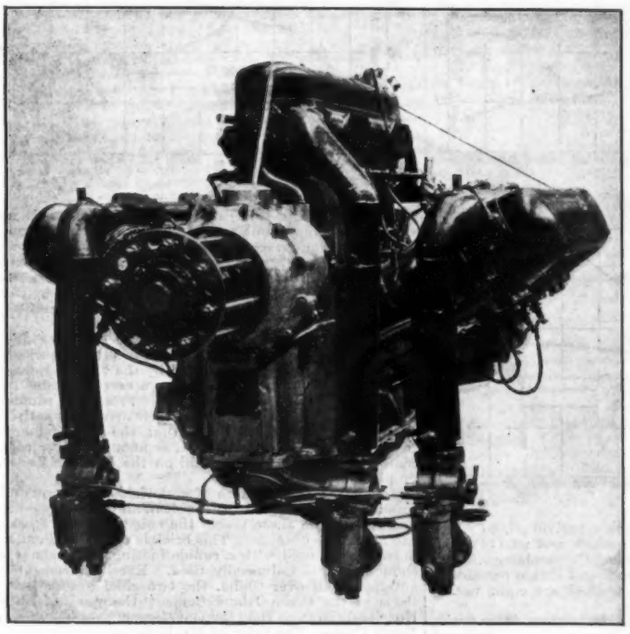


FIG. 48. NAPIER LION.

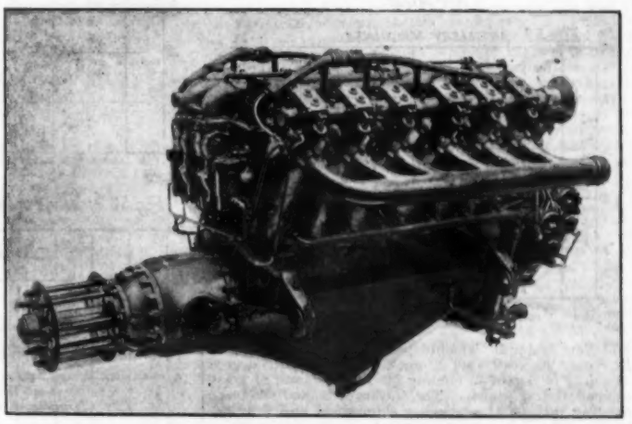


FIG. 49. 350 ROLLS-ROYCE EAGLE VIII.

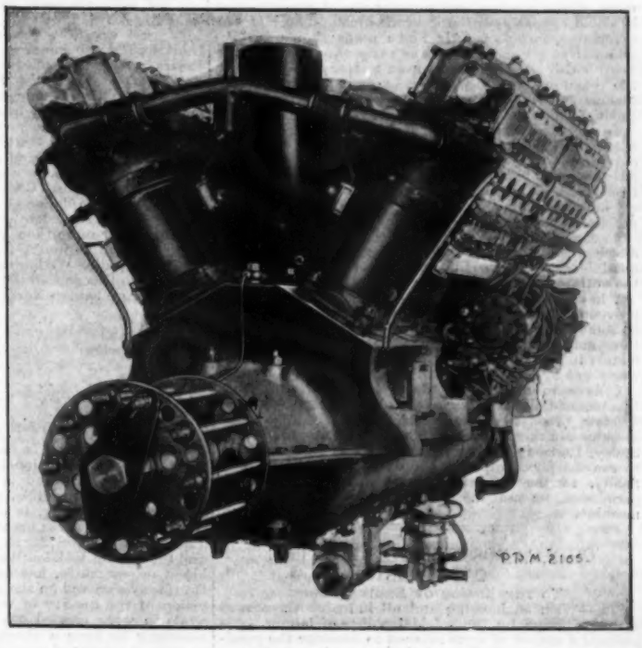
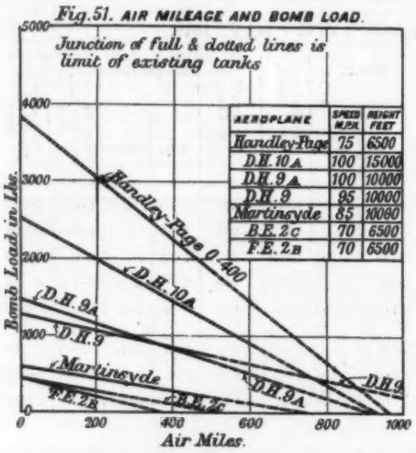


FIG. 50. 550 GALLOWAY ATLANTIC.

DEVELOPMENT OF AIRCRAFT PERFORMANCE DURING THE WAR.

Fig. 51. AIR MILEAGE AND BOMB LOAD.



AEROPLANE	SPEED M.P.H.	HEIGHT FEET
Handley-Page	75	6500
D.H.10A	100	15000
D.H.9A	100	10000
D.H.9	95	10000
Martinsyde	85	10000
B.E.2C	70	6500
F.E.2B	70	6500

Fig. 52. ARTILLERY MACHINES.

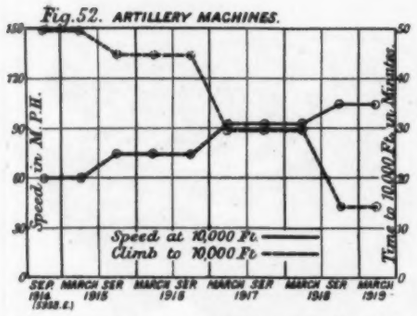


Fig. 53. RECONNAISSANCE MACHINES.

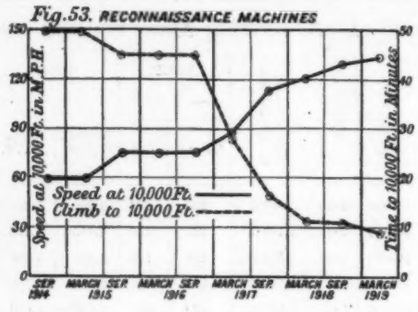


Fig. 54. SINGLE SEATER FIGHTERS.

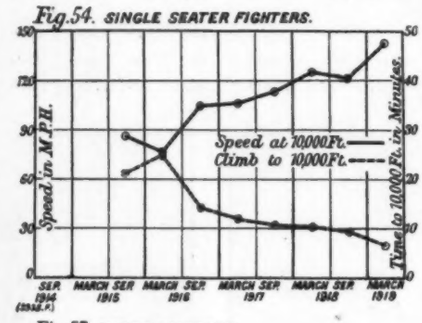


Fig. 55. TWO SEATER FIGHTERS.

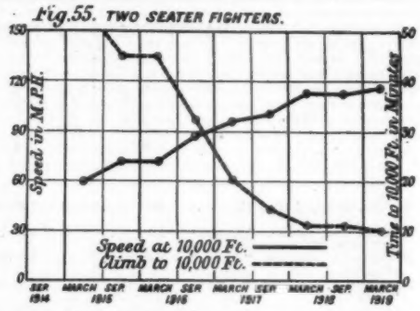


Fig. 56. DAY BOMBERS.

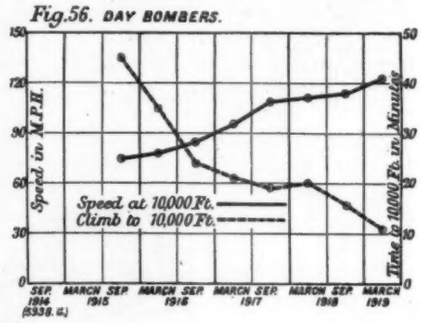
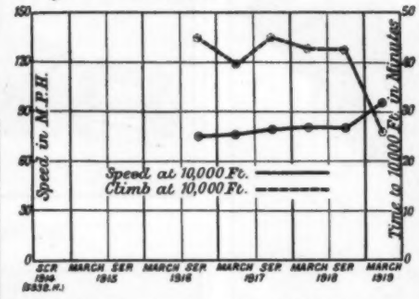


Fig. 57. NIGHT BOMBERS.



and New Zealand. The independence of the flying boat in regard to costly aerodromes, and its higher degree of safety in regard to landing places is a factor of great immediate importance. The Government and the large existing transport companies, shipowners and railways might well collaborate in their early efforts, as the initial financial results will not be healthy enough for entirely new enterprises.

Another aspect must not be neglected—the encouragement of the sporting and popular use of aircraft—and it would appear essential that the great number of war aeroplanes surplus to Air Force needs should be distributed at a low price and as early as possible to the many small enterprises and even to individuals so that the community at large may have their present enthusiasm and interest in aviation maintained and encouraged.

In technical development of design our Air Ministry must spend money by development contracts, as private enterprise will not be able to support the developments for some considerable time. This applies in particular to engine development. Attention should also be devoted to improvements in landing carriages and landing problems, also the reduction in fire risks.

In conclusion, it would appear that the future rate of development will depend almost entirely on the permissible rate of expenditure and on the efficiency of the outlays.

I have to express my regret that lack of time has prevented this paper from becoming more than a series of somewhat disconnected notes, but it is hoped that these may prove to record some of the more outstanding factors in one of the many great wonders of the world war.

I have to express my deep debt of gratitude to Lieutenant-Colonel Ogilvie and his partners, Messrs. Bristow, Pippard and Watts, for their invaluable assistance in the preparation of the paper, also to General Seeley, Under Secretary of State for Air, for permission to use the photographs of the different machines, and, finally, to the different aeronautical contractors for permission to use the photographs of the different machines.

CHINA'S POSSIBILITIES FOR THE CAPITALIST.

TO THE EDITOR OF ENGINEERING.

SIR,—With engineering and all industry threatened with extinction by the suicidal policy of labour, it is perhaps a matter of some interest to consider the possibilities of the profitable employment of capital in a country where the labour problem is non-existent, and where there is also an unlimited supply of raw material.

Starting with the coal mining as the basis of all industry, the wages of the Chinese miner in a mid-China colliery are, approximately, 6½*d.* to a maximum of 1*s.* per day, and rather less in North China, where the bulk of the coal is produced. Compare this with the daily wage of 12*s.* in force in England, and also consider that the Chinese miner is a sober individual, to whom contracts are not made to be broken, and who is amenable to a just discipline. Further, Chinese labour in this and all industries is unorganised, and strikes practically unknown. The usual hours worked are eight underground and ten on the surface.

The cost of coal at the pit head to the producer varies from 1*s.* 4*d.* in the case of the Japanese-owned Fushun* mines in Manchuria, to about 1*s.* 8*d.* in the case of the Kailan mines in North China. This is at pre-war exchange of 1*s.* 8*d.* to the dollar at present worth nearly 3*s.* 6*d.*

Coal can be loaded by hand labour if necessary at a cost of rather more than ½*d.* per ton, into railway cars, and is carried as fourth-class goods at a cost of about ½*d.* per ton-mile. With regard to the cost of other labour essential to this and all industrial enterprise, the following wages are paid in North China :—

Coolies	4*d.* to 6*d.* per day.
Carpenters	6*d.* per day.
Bricklayers	6*d.* per day.
Masons	6*d.* per day.
Fitters	10*d.* per day.
Blacksmiths	10*d.* per day.
Engine-drivers	1*s.* 8*d.* to 2*s.* 6*d.*
First-class clerks, &c. ...	4*l.* per month.

Labour, of course, is not so efficient as in Europe, but this is not proportional in the least to the difference in rate of pay. All labour is worked on the petty contract system as far as possible, and if adequately supervised and treated properly, is capable of turning out good work. In some works notably the Sakako Works of the Japanese-controlled South Manchuria Railway system and the Peking Mukden Railway Works, a bonus system based on estimates, has been introduced with success. On this system and on the petty contract systems, supervision of the quality of work done is the main thing, while in work carried out on a day basis, it is very necessary to keep a check on the numbers employed as well—a matter of great difficulty in China.

With regard to the capability of skilled labour, masons and bricklayers are poor, but can be trained to do decent work, carpenters do as well as can be expected from the rather primitive tools used by them, and can be trained to do work which will compare favourably with that turned out in Europe. Fitters and blacksmiths are of quite average ability, and the Chinese make quite capable engine-drivers. As electricians they are poor for work of finer quality, but men are easily obtainable for ordinary routine work, wiring, &c. Generally, labour in China is possessed of a high order of intelligence, is sober and contented, but incurably lazy if opportunity offers.

There is an unlimited supply of the cheaper skilled labour, and an ever-increasing supply of the mechanic class due to the numbers trained by the various railway shops all over the country, where a certain amount of European foremen are employed. From the running departments of the railways the white driver has entirely disappeared. It should be said that the cost of labour in Hongkong and South China, is about 100 per cent. more than in North China and on the Yangtse Valley, 50 per cent. more.

Turning to the question of materials of construction, bricks of fair quality are available in all the treaty ports, and away from these places the soft blue native brick can always be obtained. This brick is porous and underburnt, but if used with a rubble footing, is satisfactory enough, and is universally used. Excellent cement is obtainable all over China, the two chief brands being those of the Green Island Cement Company of Hong Kong and the Chee Hsin Cement Company of Tangshan, North China. The price of the latter cement is about 2*l.* per ton on cars at the works. Lime is universally used by the natives, and can be obtained practically everywhere, the price in North China being from 5*s.* to 6*s.* per ton in the coal districts; it is almost without exception non-hydraulic, and makes poor concrete, but is satisfactory in mortar, especially with a slight admixture of cement. In foundations of buildings, especially in new banks, very large use is made of what is known as lime and mud concrete, which is merely a mixture of 6 of mud to 1 of lime rammed in 6-in. layers. Fireclay is obtainable in the coal districts and costs about 1*l.* to 10*s.* per ton in North China, according to locality.

Timber is very expensive, and its use should be avoided as much as possible, as the great extremes of temperature in most parts of China cause rapid deterioration. At present the cost of Oregon pine is about 7*l.* per 1,000 B.M., while that of Manchurian timber, which is not as good as Oregon, but is good enough for most purposes, is 5*l.* per 1,000 B.M.

Roofing material is a great problem, as galvanised iron, the best, but not entirely satisfactory, has reached the enormous price of nearly 9*s.* a sheet, or about eight times its pre-war figure. Of other coverings, cement tiles locally made are the cheapest of all, and are very largely used. There is also some demand for patent roofing felts. Owing to extremes of temperature, most roofs eventually leak in the very heavy rains, which are usual in the country.

Manufactured iron and steel is at present enormously costly, as all the local product is taken by Japan, China being practically dependent on America. Ordinary bars cost about 28*l.* per ton, rails 25*l.* per ton, and steel plates as much as 80*l.* per ton. The great possibilities of steel manufacture in China are perhaps not sufficiently realised in Europe. As pointed out above, there is an unlimited supply of cheap labour, and there is abundant raw material. Lime stone, quarried under most primitive conditions, without rock drills, modern explosive or efficient transport, costs in North China about 1*s.* per

* This cost has lately increased, but cost in North China remains stationary.

ton. There is abundant coal of the coking variety, which is sold to the railways, who have special* rates, at 6*s.* 8*d.* per ton for lump, and 3*s.* for dust coal from which coke can be made, and which can be used for steam raising. The ore deposits of North China need investigation, but rich deposits are believed to exist within economical reach of the coal fields worked. The following is an estimate made by an American authority of the cost of production of steel at the Penchihu† Steel Works in Manchuria—a concern under Japanese management, but in which conditions would not differ greatly from those in North China :—

Materials—	*s.*	*d.*
Ore, 1·9 tons	9	0
Coke, 1·25 tons	6	2
Flux, 0·52 tons	1	0
Materials for 1 ton pig-iron... ...	16	2 cost.
Labour and Office Charges—	*s.*	*d.*
Labour, per ton	4	0
Operating stores, per ton	3	6
Salaries, per ton	0	5
Miscellaneous	2	1
Total labour cost per ton	10	0
Total cost of 1 ton pig-iron ...	26	2

This estimate is based on the assumption that Chinese labour is half as efficient as that in the United States. Further, this cost of materials is about double that in North China for coal and flux, while that for ore is certainly on the safe side, judging from the fact that Japanese-controlled‡ ore mines on the Yangtse Rivers where wages are higher than in North China by 50 per cent., bring the ore to the river bank for 4*s.* per ton, including 5 miles of rail transport, and it is stated that this could be reduced.

When it is considered that the price of pig-iron manufactured in England has reached the abnormal figure of over 8*l.*, that manufactured iron is up to over 16*l.* per ton, and that production costs are not likely to decrease with labour in its present frame of mind, it would appear to be worth while considering steel manufacture for the East in the East. The only possible competitor is Japan, who is mainly occupied with her own needs, and whose product is inferior. Further, in this way the extinction of British trade in the Far East as the result of American competition (which works untrammelled by labour troubles, and with the advantage of half the sea distance), would be prevented. In addition, British steel manufactured in China would be in a position economically to supply much of the needs of our Far Eastern possessions, and would render possible the development of the ship-building industry of Hongkong, now handicapped by imported steel and coal at 3*l.* per ton.

With regard to the question of suitable locality for the foundation of a steel industry, the first essential is, of course, the proximity of a large and certain coal supply, and this at present is only obtainable in North China on the Peking Mukden Railway, or in the neighbourhood of Hankow, on the Yangtse River. Land in a suitable locality on the Peking Mukden Railway could be purchased for 60*l.* an acre, but to buy land outside the limits of foreign concessions the co-operation of Chinese capital, or of a sino-foreign§ concern already holding land, would be required. Land free from these restrictions in the neighbourhood of a treaty port, like Hankow, might cost six times as much. The most suitable locality from every point of view, except that of supplies, is undoubtedly the colony of Hongkong, where we lease nearly 400 sq. miles of land, but the development of Hongkong industrially depends on the speedy completion of the Canton Hankow Railway, which would secure—on development—an adequate supply of all the essential raw materials of industry. At present it is handicapped by very expensive coal imported from either North China or Japan, and the necessity to import practically all essentials except cement.

Lastly, it should be said that America is already beginning to realise the possibilities of manufacture in China, and has already initiated two or three enterprises, of which the factory for the manufacture of electric lamps in Shanghai is the best known. If we wish to retain our hold on trade in the Far East, and thus take a hand in the huge and profitable work of the development of China, similar experiments should be tried without delay.

Yours truly,

June 2, 1919. AN ENGLISH ENGINEER IN CHINA.

UNIVERSITY "MATHEMATICS FOR ENGINEERS."

TO THE EDITOR OF ENGINEERING.

SIR,—The British engineering student is by no means intellectually inferior to his Continental and American rivals; but I am afraid he is still being seriously handicapped by inferior teaching. His mathematics, for example, he generally gets from some university man who is (or pretends to be) incapable of seeing anything wrong with the teaching that has been usual in this country. I have written on this matter to many of our universities and technical schools; but (with one honourable exception that I am not at liberty to name) they all seem determined to go on misleading their students with erroneous teaching, in preference to admitting that they have done so hitherto.

A striking example of this "university spirit" is afforded by the University of London. One of its lecturers in engineering mathematics has just published a book on the subject; but, on my drawing the attention of the university to the matter that I deal with in the next paragraph, I merely received an evasive reply (more worthy of politics than of mathematics) with a clear intimation that they object to having their teaching corrected by me.

In the section of the book that deals with "Simpson's rule" (that is, Simpson's first or one-third rule), the student is told that the rule gives perfectly correct results when the portions of the curve between the ordinates are straight or parabolic. Accordingly, to take a very simple example, he would think that the area under the parabolic arc of $y = \sqrt{x}$ from $x = 0$ to $x = 2$ is $\frac{1}{3}(0 + \sqrt{2} + 4) = 1{\cdot}8047$ correct to five figures. But this is not even correct to two figures; for (as is easily proved by integration) the proper five-figure value is $1{\cdot}8856$.

In place of the misleading statement here referred to, I would state the following fact that does not appear to be generally known to our teachers of engineering mathematics, though they will easily be able to prove it :—

"Simpson's one-third rule gives perfectly correct results when the portions of the graph cut off by the odd ordinates have equations of the form $y = ax^3 + bx^2 + cx + k$, where a, b, c or k may be positive, negative or zero; but it does not give perfectly correct results when any higher power of x is introduced into this equation, except when the new index is odd and the extreme values of x are numerically equal."

We shall, accordingly, get a perfectly correct result by using the rule, with three ordinates only, for $y = x^3$ between any two values of x, or for $y = x^2 + x^5$ between $x = -2$ and $x = 2$, but not under any circumstances for $y = x^2 + x^4$.

With your permission, I will later on deal with some other and more serious errors in our university teaching of mathematics for engineers. The first of these will be in connection with the hyperbolic functions, where British engineering students are being misled, while Americans (and probably Germans also) are being taught quite correctly.

Very respectfully,

W. F. DUNTON.

165, Tamworth-road, Newcastle-on-Tyne.
July 21, 1919.

GAS CYLINDERS.

TO THE EDITOR OF ENGINEERING.

SIR,—There is a printer's omission in the last paragraph of my letter in your current issue. As this omission leaves the paragraph somewhat ambiguous, I wish to point out that after the word "Government" my letter should read as follows :—". . . will follow the example of France and sell or even hire *their surplus cylinders to the trade* on reasonable terms." The words in italics are those omitted, and I shall be obliged if you will publish this correction.

Yours truly,

K. S. MURRAY.

(The British Oxygen Company, Limited.)
Elverton-street, Westminster, S.W.1.
July 21, 1919.

A THEORY OF THE FLOW OF WATER OVER A CANAL WEIR.

TO THE EDITOR OF ENGINEERING.

SIR,—The formula for calculation as to the discharge over a simple weir in a still water reservoir, seems to give fairly satisfactory results, but the formula for the discharge over a canal weir does not seem to yield results that are satisfactory. The formula for canal weirs is arrived at by taking into consideration the velocity of approach, and by adding this to the formula for discharge over a simple weir from a still water reservoir. If the velocity of approach was the only difference between the two cases, the existing formula would probably be the best procurable, but there seems to be other differences which may possibly account for the formula proving unsatisfactory.

The water flows from the reservoir without any swirls appearing on the surface, and the flow may be said to be non-sinuous motion not only when the water passes over the weir, but when it flows towards the weir. The water flows in a canal in turbulent motion and swirls are seen on the surface, consequently the motion of the water in the canal has to change from turbulent to non-sinuous motion when passing over the weir. There is also a change of the relative velocity of the upper and lower layers of the water. When the water flows in a canal the velocity of the upper layers is greater than that of the lower layers. When the water flows over the weir the velocity is least on the surface and greatest at the bottom, consequently there must be a considerable increase in the velocity of the lower layers before the water can pass over the weir. There is also a gradual decrease in the surface fall of the water from some distance above the weir, and just above the weir the surface is practically level. If this latter peculiarity is not allowed for, when designing the weir, the bed of the canal is scoured out and the surface is lowered, which seriously affects irrigation, when the surface fall is about 1 ft. per mile or over. This lowering of the surface level ceases when the natural conditions of flow over a weir have been obtained.

As the difference between the flow of water over a reservoir weir and a canal weir is not a mere difference of velocity of approach, it seems advisable to discover some rational theory that accounts for the difference, in order that it may be possible to construct not only a new formula for discharge, but also for the height to be added to the canal weir, in order to obtain the necessary level for irrigation in the canal above the weir.

For various reasons it would seem that in order to obtain a theory, the question of resistance to flow must be gone into.

When water flows from a still-water reservoir over a simple weir, there is no observable surface fall except at the weir itself, the surface is smooth and unruffled by eddies on the surface, consequently the flow is not in turbulent motion. The flow is what may be called non-sinuous throughout, and the ordinary resistances seem to be absent. Force is, however, required to overcome the inertia of the particles that fall over the weir; fresh particles are constantly being moved, and work is constantly lost in overcoming the force of inertia, not only when the particles are first moved, but also when the velocity of the particles is increased. The water flowing over the weir may be said to do work in overcoming the resistance due to inertia. If it were not for this resistance the water would flow over the weir at a great velocity. The force of inertia on each particle is probably extremely small, but collectively considerable.

When the water flows over a canal weir, the water being in motion, the inertia due to the initial movement of the water has not to be overcome, and consequently the velocity at the weir would be increased; but the water flows towards the weir in turbulent motion, which must cease before the water can flow over the weir in non-sinuous motion. Little is known of turbulent motion except that it is due to eddies or puffs of water that start from the bottom layers of the flowing water and come to the surface at some distance down stream from their place of origin. If it is assumed that the draw of the weir stops the action of the puffs, by decreasing the pressure in front of the particles of the lower layers of the flowing water, and thereby increasing their velocity, there would be no greater resistance than that caused by increasing the velocity of the lower layers of the flowing water.

At the section in which the puffs cease to form, the velocity of the bottom layers of flowing water would increase considerably, and the layers above would still be under the influence of the resistance due to the puffs that start higher up. As the water flows towards the weir the puffs come to the surface, and less water is retarded by them, consequently the mean velocity of the water increases towards the weir. As the resistance due to turbulent motion ceases, the surface fall, which may be said to be required to overcome the resistance due to turbulent motion, will cease also. The resistance a little above the weir will be due to the puffs that still rise to the surface, and as there is no surface fall the water would come to rest if it were not for the draw of the weir.

The action of the water flowing over the weir may be shortly described as follows :—

The draw of water flowing over the weir causes the resistance of the water, flowing in the canal, gradually to cease, which allows the velocity to increase from that of the canal to that of the weir, and gradually renders surface fall unnecessary. The surface fall being unnecessary, the bed is scoured out and the surface fall is increased all the way up to the canal reach, from the point where the surface fall commences to decrease.

This theory does not seem to give directly a formula, but it seems to show that the velocity of approach should be the velocity of the canal above the portion which is influenced by the weir, and that any experiments taken to obtain coefficients should not be made in troughs with hard unerodable beds which do not allow scour to take place, and prevent the natural change of surface fall above the weir.

In order to obtain the height required to be added to the crest of the weir, to maintain surface levels for irrigation, it is necessary to find out the distance from the weir where the surface fall commences to decrease. This would seem to be the distance the puffs travelled before they come to the surface, and would depend on the surface fall of the canal above the influence of the weir corrected by the depth, as, the less the depth, the less the distance travelled by the puffs in coming to the surface.

It is often assumed that scour is due to the velocity being too great, but if it were so in this case the scour would increase as the surface fall increased, consequently there would be no limit to the scour, and irrigation would be affected very much more than it is. The surface fall above a certain amount would also be impossible unless the bed was lined with unerodable material. The theory of the flow over a canal weir described above gives a limit to the scour, as when the water has scoured the bed sufficiently to obtain the natural surface fall, no further scour takes place. No theory would seem to be correct unless it gave a limit to the inevitable scour.

This theory of the water flowing over the canal weir necessitates a portion of the wetted sectional area being unrequired by the main stream of water flowing over the weir. This unrequired space is triangular in shape, being bounded by the bed, the face of the weir and the stream of water flowing towards the weir.

In this triangular space a current is formed owing to the reduced pressure caused by the high velocity of the water as it flows over the weir; this current flows towards the weir close to the main current flowing over the weir and in the same direction: at the weir wall it flows downwards, and there is a return current along the bed. This current is therefore continuous, and the

* The ordinary retail price for coal is 8*s.* 4*d.* for dust, 13*s.* 4*d.* for lump, 20*s.* for coke, but this is for small quantities, and for 80 miles rail haulage.

† Works using 70 per cent. to 40 per cent. ore with a daily output of 250 tons.

‡ Steam navvys as employed in England would probably reduce ore costs considerably.

§ Such as the Chinese Engineering and Mining Company in North China, and the Peking Syndicate in the Hankow district.

same water flows round and round the triangular space; it is an entirely separate current to the main current, but it is practically impossible to find out the dividing line between the two currents, and consequently any attempt to measure the velocity of the main current of the water approaching the weir by means of current meters is not likely to be successful. The return current moves any particle of silt that may fall to the bottom along the bed to the place where the main current leaves the bed and commences to flow upwards, when the silt reaches this place the particles are lifted up into the main current in the same way as a piece of paper is lifted off the table by blowing over it. In the same way stones that may be rolled along the bed of the canal are lifted into the main current when they arrive at the same spot. It follows from this that if the lifting power is too small, the silt will remain and a deposit of silt will form.

The lifting power of the current will, according to Bernouilli's theory, increase with the square of the velocity of the main current as it leaves the bed, and the velocity of the current in the triangular space will vary with the square of the velocity of the water just before it passes over the crest of the weir.

The determination of the point where the surface fall commences to decrease, by means of surface measurements, is almost impossible; but as the point is just above where the main current leaves the bed, it is better to determine this point either by measuring the deposit of silt or else by observing the place where the particles moved along the bed are lifted up into the current. The latter method presents little difficulty if the observations are carried out in the clear chalk streams of Southern England.

L. L. WICKHAM.

July 10, 1919.

ENGINEERING TRAINING FOR DEMOBILISED OFFICERS.

TO THE EDITOR OF ENGINEERING.

SIR,—With regard to the State scheme of University training for ex-officers and men of the Forces, I doubt whether in all cases the young men are being properly advised by the Army authorities. The following case came to my notice a few weeks ago.

A young man who had been in an architect and surveyor's office for about two years and had been in the Army for three or four years was recommended by the Army authorities to take a course in surveying at a certain institution, and the young man understood that this course was to equip him for earning his living. Some doubt having been expressed as to whether he had properly understood his advisers, he approached them again, and they were still of opinion that this course would fit him for occupying some paying position. The idea that a course of six months or so studying and practising the one subject of surveying was to fit a man for business seemed to me rather absurd, and I recommended the youth that the money to be spent on him should go towards a premium to a practising surveyor and valuer who could teach him a real business. It appears that this is a possibility in such cases.

But there must be a great many ex-soldiers who are taking advantage of the scheme under the belief that the training will equip them for occupying a position and earning a living.

On the other hand, I know that some men are getting into engineering works and drawing offices to make sure of their practical training, and they are studying privately, and with the aid of correspondence colleges. This is, I think, an excellent way, although I do not believe that this is as good as the training they might get in theory at any University.

The subject is an extremely important one, and I think that it should be thoroughly ventilated in the columns of ENGINEERING.

Yours truly,

July 22, 1919. PRACTICAL ENGINEER.

REDUCED COAL PRODUCTION OR ECONOMY.

TO THE EDITOR OF ENGINEERING.

SIR,—At the last sitting of the Coal Commission, Sir Richard Redmayne indicated a line of action which if adopted in our homes and works would greatly minimise, if not entirely remove, any danger of industrial restrictions through reduced coal production.

It is a business truism that where the demand for any commodity is in excess of supplies its price increases, and as the commodity in this case is coal the very base and foundation of all our industries, the seriousness of the position is patent to every one, and therefore calls for individual action. It does not require any great effort of imagination to know that dear coal means dear iron, steel, copper, brass, &c., and therefore the machines from which they are built increase in price proportionately, and such increase is further reflected on the price of our clothing, furniture, food, building material and, in fact, on every article we produce or buy.

For steam-raising and domestic purposes we now use about 180,000,000 tons of coal per year, 25 per cent. to 30 per cent. of which can be saved by adopting the same common sense methods of proportions with our boiler furnaces and domestic fires as are in daily use in our manufactories. In the making of any commodity, from steel to bread, exact rules are followed and positive results are secured every time, but in handling our home fires and boiler furnaces chaos in the majority of cases holds sway, hence the loss of about 1,000,000 tons of coal per day.

If our domestic grates were made to give an area of 1 sq. in. for each 7 sq. ft. to 9 sq. ft. of floor space, the exact proportions depending on window surface, &c. and the coal added to the fire in small quantities, and whilst the fires are bright, the cinders being used over again, fully 15,000,000 tons of coal per year would be saved.

In our boiler furnaces, instead of supplying 18 lb. of air per pound of coal, we generally allow the air supply to reach 30 lb. or over, and instead of a furnace temperature of 2,700 deg. we secure one of 1,700 deg., the radiating power of which is less than one-half that secured with the smaller quantity of air, and therefore we send nearly 30 per cent. of the heat in the fuel up the chimney in the form of smoke and other products of imperfect combustion, instead of into the boiler to produce steam.

The above practice may be taken as alone responsible for the loss of millions of tons of coal per year, but this is greatly increased by the lack of uniformity between the furnace areas and outlets for the gases in different-sized boilers, and until this defect is remedied little progress in coal saving can be effected. Any one sufficiently interested to go carefully into this subject will find a boiler 7 ft. in diameter has 1 sq. ft. of gas outlet for each 4 sq. ft. of furnace, whereas a boiler 9 ft. diameter provides 1 sq. ft. of outlet for the gases for every 2¼ sq. ft. of grate, the proportions varying in all the intermediate sizes of boilers.

Under the above general conditions it is impossible to secure uniform results as the ratio between grate and outlet is the factor which decide both the duty and efficiency of a boiler, but here we have proof that 4 sq. ft. of grate is provided in one boiler to do the same work as 2¼ sq. ft. in another boiler of the same type, and yet we grumble that a coal shortage is probably a possible condition which can be easily prevented and without cost.

By a general reduction in grate areas in our boiler until the proportion of grate to outlet is 2 to 1, thicker fires could be worked, a reduction in excess air would naturally follow, and a higher furnace temperature be secured; smoke would then be greatly minimised and an increased evaporation secured per pound of coal burned.

If the steam user and householder are not sufficiently alive to their own interests the Government should make the more scientific use of coal compulsory, and especially in the working of steam boilers where the overall efficiency is very often below 60 per cent., whereas with properly-designed furnaces and careful stoking 80 per cent. efficiency can be exceeded.

If the suggestions briefly outlined were put into practice a reduction in our coal supply could be ignored, as we should reduce our consumption by not less than 50,000,000 tons per year, and by bringing the demands more in line with supplies the stability of the general trade throughout the kingdom would be assured, and the coal saving can be effected by united action. Why is it not done?

Yours faithfully,

W. H. CASMEY.

Milnthorpe, Wakefield, July 7, 1919.

EXPANSION OF MOLYBDENUM.—As molybdenum wire now finds considerable application in the leads of X-ray tubes and for other purposes, Lloyd W. Schad and Peter Hidnert, of the Bureau of Standards (Scientific Paper, No. 332) have determined the thermal expansion of an exceptionally pure specimen containing 99·85 per cent. of molybdenum between the temperature limits − 142 and + 305 deg. C. The results obtained are expressed in two formulæ, the first of which may be used for the low temperature range − 142 to + 39 deg. C., and the second for the higher range + 39 to 305 deg. C. If L_0 be the length at 0 deg. C., and L_t the length at temperature t, then $L_t = L_0 (1 + 5{\cdot}15\ t \times 10^{-6} + 0{\cdot}0057\ t^2 \times 10^{-8})$, and, secondly, $L_t = L_0 (1 + 5{\cdot}01_5 \times 10^{-6} + 0{\cdot}00138\ t^2 \times 10^{-8})$. The probable error is said not to exceed 3×10^{-6} of unit length.

EFFECT OF FRENCH RAILWAY NATIONALISATION.—In a manifesto published on June 2, the Federation of Railway Employees protested against the proposed rise in rates, and suggested as an alternative the nationalisation of all the French railways. Commenting upon this, the *Journal des Débats* of June 7, points out that a rise in rates is inevitable in view of the huge deficits on working—5½ milliards fr. in 1914–19, and 3 milliards fr. for 1919 alone. But would nationalisation benefit the users of the railways or the Exchequer? It is easy to answer the question by comparing the working co-efficient of the State system, which was 120 per cent. in 1918, with 87 per cent. for the Midi, 85 per cent. for the Paris-Orléans, and 90 per cent. for the Paris-Lyons-Méditerranean. The State figure exceeds even those of the companies serving the liberated districts:—96 per cent. for the Est, and 112 per cent. for the Nord. A comparison has been made between the Ouest system purchased by the State and the Orléans system, which have a very similar traffic both in kind and length of haulage. The Orléans deficit for the last 10 years (1909–1918) reached 241 millions fr. If, instead of being worked at a working co-efficient ranging from 52–85 per cent., the co-efficient of the Ouest had been employed (68–120 per cent.) the deficit would have exceeded 1,200 million fr. From these figures the cost of complete nationalisation to the taxpayers may be guessed. The Federation, moreover, omits to mention that not the least of the causes of the actual deficits of the lines is the rise in wages of the personnel. Before the war the employees of the great railways earned about 800 million fr. In 1919 they will share out nearly 4 milliards fr., or an increase of 400 per cent. A rise in rates is unavoidable, and the increased revenue thus gained will be accompanied by the reduction of work owing to the general adoption of the eight-hour day.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

Iron and Steel.—All extraneous affairs are overshadowed by the strike in the South Yorkshire coalfield, which will have a disastrous effect not only on the steel and allied industries of the district, but on every phase of industrial and commercial activity. Already many of the heavy trades are seriously affected, thousands having been thrown idle, and responsible men agree that a continuance of the trouble for a week will mean the closing down of every one of the big works, with the consequent unemployment of hundreds of thousands in Sheffield alone. Inquiries to-day show that Vickers, by strictest economy, hope to see the week out. At John Brown's, many departments are already closed. Steel, Peech and Tozer have all their principal departments standing. Bessemer's state their stocks of coal will be exhausted to-night. Cammell's may last to the end of the week. Like reports come from all. As shortage becomes acute, department after department is shut down, leaving the most urgent till the last. The lighter industries—cutlery, edge tools, files, saws and the like—are better off. Many are run by gas and electricity, but even these it is officially stated, are to be drastically curtailed. The Sheffield Electricity Supply Department state that they can carry on for four or five weeks on full load, and with restricted use by manufacturers, for considerable period longer. Generally, however, the outlook is gloomy for both employers and employees.

South Yorkshire Coal Trade.—The strike of the Yorkshire miners in consequence of the refusal of the Government to grant their demands for a full seventh, or 14·3 per cent. advance, to make up for the reduction of hours under the Sankey award, has come as a bombshell upon the country. Few stocks were held either by manufacturers or merchants, and business is absolutely at a standstill. The following new quotations came into force on Monday, but in view of the situation, are merely normal. Quotations:—Best branch handpicked, 33*s.* to 34*s.*; Barnsley best silkstone, 33*s.* to 33*s.* 6*d.*; Derbyshire best brights, 31*s.* to 32*s.*; Derbyshire house coal, 28*s.* 6*d.* to 29*s.*; Derbyshire best large nuts, 28*s.* 6*d.* to 29*s.* 6*d.*; Derbyshire small nuts, 27*s.* 6*d.* to 28*s.* 6*d.*; Yorkshire hards, 28*s.* 6*d.* to 29*s.* 6*d.*; Derbyshire hards, 28*s.* 6*d.* to 29*s.* 6*d.*; best slacks, 24*s.* to 25*s.* 6*d.*; nutty, 23*s.* to 24*s.*; smalls, 19*s.* to 20*s.*

THE SITUATION IN GERMANY.—Mr. Arbel, a manufacturer in the North of France, who had gone to Germany to recover his stolen machinery, relates with stupefaction what he saw there. Germany, he says, is economically stronger than before the war, for she has increased her means of production, both agricultural and industrial, by reason of the machinery she has stolen and even now continues to use. Her ironworks are formidable and work at high pressure, whilst two-thirds of the French ones are destroyed. Her crops are superior to those he has seen in France from North to South. Her farms are stocked with stolen cattle and horses. Thanks to her chemical knowledge she has made wonderful progress in intensive cultivation. Her workers and traders are at their posts, and their means of production formidable. Mr. Gustave Hervé, in *La Victoire*, warns France that the Germans seem to be the only people realising that the most intensive production can alone save the nation. Mr. Arbel is of the same opinion. Germany is working with a feverish activity, which we would regard with admiration if it did not threaten to submerge us. Why did not the Allies, especially the French and Belgians, make it one of the conditions of the Armistice that all stolen machinery should cease to be used? There is, perhaps, still time to bring forward this question.

INDIA AS A HARDWARE MARKET.—India is a particularly important market for British supplies of hardware of all kinds. Before the war, says *The Board of Trade Journal*, India's imports of cutlery, implements, and tools (excluding agricultural and machine tools) from the United Kingdom amounted to nearly 300,000*l.* in value, and of hollow-ware, and sundry small hardware to 322,000*l.* In spite of the larger consuming power of the Indian Empire and the consequent increased demand for imported goods, Great Britain only succeeded, owing to difficulties arising from the war, in supplying such goods to India in 1917 to the value of 230,000*l.* and 107,000*l.* respectively. The Indian market for builder's hardware, such as locks, hinges, door-bolts, &c., was worth annually about 150,000*l.* before the war, and this figure represents, approximately, the value of these imports in 1916–17, although actually the quantity imported works out at less owing to the increase in prices. In domestic hardware, including enamelled ironware, the position formerly held in the import trade by Germany and Austria has not been completely filled, although Japan has made enormous progress. Greater use has, of course, been made of home-manufactured substitutes for the foreign article. Nevertheless, a big business awaits the British manufacturer who can put a cheap article on the market. The British position has not been seriously assailed with respect to instruments and tools generally. Here it is a matter for Great Britain to continue to supply her well-known lines, keeping the price as low as possible in view of the competition of Japanese and locally produced substitutes, and of the well-finished American specialities. In cutlery it may be said the market is waiting for the full resumption of British supplies. In addition to the light hardware goods indicated above, India imports a total value of over 1,000,000*l.* worth of heavier hardware, including sugar mills, oil presses, water lifts, and dairy appliances, over three-quarters of this trade belonging to the United Kingdom. Here again American and Japanese competition is steadily increasing.

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Scotch Steel Trade.—Business in the Scotch steel trade is at a standstill this week, as all the establishments are on holiday. Work is to be resumed on Monday, 28th inst., but it is doubtful if operations will be in full swing until the end of next week or the beginning of the following one. At present some extensive repairs are being effected and plant overhaul is general. Before the holiday stoppage a large output took place, but despite that order, books are still well filled. The matter of prices is the serious question at present, and the outlook has not been made any better by the announcement that coal is now up 6*s.* a ton. It was difficult enough before for some of the consumers of steel material to export their manufactures, but now the position, as regards exporting at any rate, is well nigh impossible. The result of the advance in prices of manufactured steel, consequent upon the Government increase in the price of coal, will be effectively to close down the most of our shipping trade. America, and, very soon, our late enemy, will be doing the bulk, if not all of the foreign business which used to be ours. Already quite a considerable amount of American material is finding its way over here, and further inquiries are now under consideration by the local agents. Buyers here say that they have been offered American steel at pounds per ton less than home prices. There is no doubt but that steelmakers are "up against it" at present, as the problem is a most serious one. No definite intimation has yet been made as to the course which is to be followed but the position is being carefully considered. Had the miners' conference at Keswich accepted the Government offer then, steel prices for the month of August were to have remained as at present, but now that the current price of coal has been advanced the steel quotations now ruling must necessarily be raised.

Malleable Iron Trade.—On resuming after the holidays, the West of Scotland malleable-iron makers will have quite a lot of work to commence upon, and plant will be kept running steadily for some time. As in all other industries the increased cost of fuel will tell its tale, and prices must be raised. A pronouncement to that effect is expected shortly.

Scotch Pig-Iron Trade.—The increased cost of coal has upset all calculations, and the consequent rise in prices may have the effect of reducing buying to some extent. No stocks were held before closing for the holidays, and practically nothing will be available for delivery before August 1. Revised prices will be intimated by the makers this week.

The Coal Trade.—It was learned with some interest here to-day that an announcement had just been made in the French Chamber that arrangements were being made to get large supplies of coal from America at prices under those quoted for British coal. "Taking coals to Newcastle" was a phrase often laughed at in bygone days, but now we have American coal being offered in this district. All the pits are meantime off on holiday, both in the East and West of Scotland, and rumour has it that the inevitable few extra days is very likely to be again taken this year. The total shipments of Scotch coal for this year to date is 4,041,016 tons, and for the same period last year, 4,560,469 tons, a decrease of 519,453 tons.

BRITISH COAL EXPORTS.—The Board of Trade announces that the Regular and Reliable List of Coal Importers in neutral countries is no longer in force. Applications for licences to export to firms or persons not included in the list will now receive consideration, subject, of course, to the available supply of coal.

AIRCRAFT EXHIBITION IN AMSTERDAM.—We read in *The London and China Telegraph* that an aircraft exhibition is to be held at Amsterdam early in August. Germany was anxious to be an exhibitor, but her goods were not accepted in order that England and France might take part. Holland has not a single aircraft factory of her own and requires many machines, especially for Netherlands India.

WATER POWER IN SPAIN.—Spain's water power in the various parts of the country available for immediate use for electricity has been computed as follows by *España Economica y Financiera*:—

	Kw.
Atlantic slope of Leon and Galicia ...	70,000
Asturias	40,000
Santander	30,000
Ebro above Saragossa	65,000
Rivers of the Pyrenean slopes ...	490,000
Ebro from Saragossa to the sea ...	130,000
Douro within Spain	90,000
Douro on the Portuguese frontier (falls)	150,000
Tributaries of the Douro	50,000
Tagus	110,000
Tributaries of the Tagus	50,000
Guadiana	35,000
Guadalquivir and other Andalusian rivers	40,000
Jucar and Cabril	90,000
Other Mediterranean rivers	60,000
Rivers of minor importance	500,000
	2,000,000

Certain American financiers, in co-operation with important units of the Constructora Naval, propose to found a company which will utilise all the electric power in the country, for the purpose of electrifying the whole railway system of Spain. The capital of the proposed company will be Pes.200,000,000.

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

The Cleveland Iron Trade.—Business in Cleveland pig-iron is practically at a standstill, and there cannot be resumption of activity until decision is arrived at as to what advances shall be made to cover increased cost of production, consequent upon the rise in coal, and the addition to value of Cleveland ironstone caused by the adoption of the seven-hours' day at the Cleveland mines. Producers have decided not to alter for the present the fixed maximum selling prices of iron, but a rise appears imminent in the near future, as the increased cost of make is put at 15*s.* per ton. Current production of the better qualities is all disposed of, and, indeed, there seems little prospect of foundry iron being offered for sale to any extent before next quarter, output to the end of September having been practically all disposed of. Holidays in Scotland have reduced home deliveries, and approaching local holidays will ease pressure for supplies. Under these circumstances licenses for export are being issued much more freely; but they are of little or no use, as iron is unpurchaseable. Quotations are altogether nominal at 160*s.* for No. 3 g.m.b. and No. 4 foundry; 164*s.* for No. 1, and 158*s.* for No. 4 forge for home consumption, and 5*s.* above these rates for export.

Hematite Iron.—The position of the East Coast hematite branch is somewhat different. A feeling prevails that advances are not so necessary, as they are in Cleveland iron, seeing that hematite rose 10*s.* only a week or two ago, and that since that fall in price of imported ore has benefitted makers, all of whom are very well sold. Nos. 1, 2 and 3 are put at 200*s.*, and No. 1 at 202*s.* 6*d.* for home use, and for export mixed, Nos. are 205*s.*; and No. 1 is 207*s.* 6*d.*

Foreign Ore.—There is little passing just now in foreign ore, the abundant tonnage offering, and downward movement of freights having caused buyers to hold off in anticipation of further fall. Steamers Bilbao-Middlesbrough are being chartered at 26*s.*, so that 55*s.* c.i.f. Tees should be a full price for best rubio.

Coke.—Sellers of coke have lost no time in raising prices 9*s.* per ton, making medium blast-furnace kind 48*s.* at the ovens, and low phosphorus quality 49*s.* 6*d.* at the ovens.

Manufactured Iron and Steel.—There are good home and foreign inquiries in the market for finished iron and steel, but business is suspended pending revision of prices. Export rates are matter of negotiation, but they are certainly higher than the following nominal quotations for home use: common iron bars, 20*l.* 10*s.*; marked bars, 23*l.*; strip iron, 21*l.* 15*s.*; ship rivets, 27*l.* 10*s.*; steel ship, bridge, and tank plates, 17*l.* 15*s.*; steel angles, 17*l.* 5*s.*; steel joists, 17*l.*; heavy steel rails, 16*l.*; steel hoops, 23*l.* 5*s*; galvanised sheets, 27*l.* 10*s.* and block sheets, 22*l.*

CHILE'S GREAT POTENTIAL HYDRAULIC POWER.—A report published by the Commercial Department of U.S.A. draws attention to the fact that, through the medium of her immense reserves of hydraulic power, Chile has a great future as a manufacturing centre, and furnishes a large market for American capitalists and manufacturers.

SOLDERS FOR ALUMINIUM.—The Bureau of Standards (Circular No. 78, by J. F. Meyer), has tested various commercial solders for aluminium, the compositions of which are tabulated. All soldered joints, it is stated, are subject to rapid corrosion unless protected from it. Suitable solders are obtained by the use of tin and some zinc, or by both zinc and aluminium within wide ranges of proportions; the solders should be applied without a flux, and at a high temperature; the adhesion is said to improve with rising temperature of the tinning operation. The tinning mixture should be special for aluminium; previously-tinned aluminium surfaces may, however, be joined with ordinary soft solder. A perfect union between solder and aluminium is difficult to obtain, according to this circular, and that is probably the general opinion; it is different with welding.

RAILWAY DEVELOPMENT IN BURMA.—The Government of Burma, says *The Board of Trade Journal*, has decided to encourage the development of railway communication by the adoption of the general British policy in the case of colonies—that in a country with a generally scanty population and no towns of considerable importance, strategic points on frontiers and general trade routes, &c., should be linked up. It is thus calculated to develop the country by first establishing the lines of communication—a policy for which, according to opinion in British India, there is ample scope also in British India itself, where, it is pointed out, the construction of feeder lines to the main lines on a wholesale scale should be prosecuted. The conditions for railway development in British India and Burma are very different from those in Australia and Canada, where large areas of useful land—arable, forest or mineral—are opened up by railways regardless of the uninhabited condition of the country. The assumption that rich territory, once opened up by means of communication will find its own development, is an axiom which, in the case of European populations, never fails. Conditions in India are different, in that the population, even when not apathetic, requires both education and capital, and the railways therefore hesitate to launch out in the matter of undeveloped areas, although these areas may urgently require means of communication for purposes of development.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Local Markets.—Labour troubles in the district continue seriously to affect the coal trade. The strike of tippers at the Bute (Cardiff) Docks has resulted in the suspension of loading operations since last Monday week, and efforts are being made by the men to spread the stoppage to the other ports in the Bristol Channel. The trouble has arisen over the dismissal of a number of tippers by the Cardiff Railway Company, owners of the Bute Docks, in consequence of a reduction in shipments, and this action, the men contend, is a violation of the minimum-wage settlement reached a few months back. A joint meeting of representatives of the Bristol Channel tippers has been held, and it was decided to meet again on Friday next, and in the meantime it was arranged that port meetings should be held to put the position before the men on the issue of recommending a general stoppage throughout the Channel on Monday failing a settlement. At the same time many of the collieries, particularly in Monmouthshire, have been rendered idle owing to the surfacemen refusing to work until their hours are settled under the seven-hours' day, while others are stopped in support of the Labour Party's demand for a withdrawal of troops from Russia. In these circumstances, business has been driven to an almost complete standstill, as operators are reluctant to enter into fresh transactions owing to the uncertainty of the outlook. The strike in Yorkshire is also aggravating the situation, for it is expected that South Wales will be called upon to meet the requirements of works in that district in regard to coal supplies, and this will mean a further reduction in the amount available for export which has already been cut down owing to the decrease in outputs. News that the Americans had secured a contract to supply France with 100,000 tons of coal, and that the Norwegian Government had placed an order for 300,000 tons of United States coal, is also viewed with seriousness, for it is recognised that these markets which were practically exclusively United Kingdom markets before the war, are being lost simply through labour difficulties, and the policy which is being pursued of restricting outputs. Colliery owners have now been officially advised by the Board of Trade of the increase of 6*s.* per ton, making an advance of 19*s.* per ton, compared with the pre-war price, for coal for home consumption, and of an increase of 6*s.* per ton on the export schedules. This advance in export schedules does not affect current business, owing to the fact that for the past couple of months prices have been anything from 10*s.* to 20*s.* over the old schedules, though there are some contracts still running, which were fixed up some time ago, at which coals were sold at under a 6*s.* premium. In these cases, for all coals shipped on and after Monday last, the prices must be brought up to the schedule. Meanwhile prices are irregular and dependent on the individual position of buyer and seller. Some collieries are still fairly comfortably situated, and indicate up to 65*s.* for the best large coals and 60*s.* has been paid, but others who are suffering from a lack of empty wagons are ready to make substantial sacrifices where spot shipment can be arranged. Small steams are worth round 45*s.*, with 50*s.* being asked.

Newport.—Stoppages in the Monmouthshire coalfield have been particularly heavy during the past week, owing to the surfacemen and enginemen refusing to work until their position under the seven-hours' day had been settled; others are on strike as a protest against the 6*s.* increase in coal prices, and others refused to work in support of the demand of the Labour Party for a withdrawal of troops from Russia. The frequency of the unauthorised stoppages are causing operators endless difficulty, for there is no certainty that after a transaction has been completed the coal will be forthcoming on the arranged date. Prices are very erratic, though Monmouthshire coals are relatively dearer than Cardiff descriptions. Actual prices, however, depend entirely on the individual circumstances of buyer and seller. For loading next week, sellers are asking 60*s.* for best large sorts, but for immediate shipment, concessions from 5*s.* to 10*s.* can be secured while smalls range from 40*s.* to 45*s.*, according to quality.

Iron and Steel Position.—The advance of 6*s.* per ton in inland coal prices has had a demoralising effect on these trades, and manufacturers are now busy in dealing with the effects of this increase. Makers, in view of the uncertainty of the future, are not disposed to take on fresh commitments, except for prompt delivery, and even in these cases, are insisting on a clause to safeguard themselves against any further increase in the cost of production. It is estimated that pig-iron prices will have to be increased by 20*s.* per ton, and the South Wales Siemens Steel Association have temporarily raised bars 10*s.* per ton to 14*l.* In the tinplate trade the inquiry is poor and American competition is viewed with alarm. Standard sizes are offered at 33*s.* 3*d.* per box, and at the same time American plates are being landed in Liverpool at 31*s.* 6*d.* a box.

THE LENS MINES.—The pits at Lens, says *Revue Générale de l'Electricite*, are flooded to the ground level, and at the lower level mines the water is flowing out over the ground, threatening flooding of the countryside. The Mining Society of Lens estimates that it will take 18 months to pump out the water, and that the working of the coal in the higher seams cannot be resumed until the end of 1920. The complete restarting of the mines of Lens and Liévin will take at least 10 years. The powerful pumps required have been on order for a long time. They will be operated electrically, and the electric supply will be taken from the generating-station at Harnes.

LOCOMOTIVES FOR RAILWAYS IN CHINA.

CONSTRUCTED BY THE BALDWIN LOCOMOTIVE WORKS, PHILADELPHIA, U.S.A.

(*For Description, see Page* 123.)

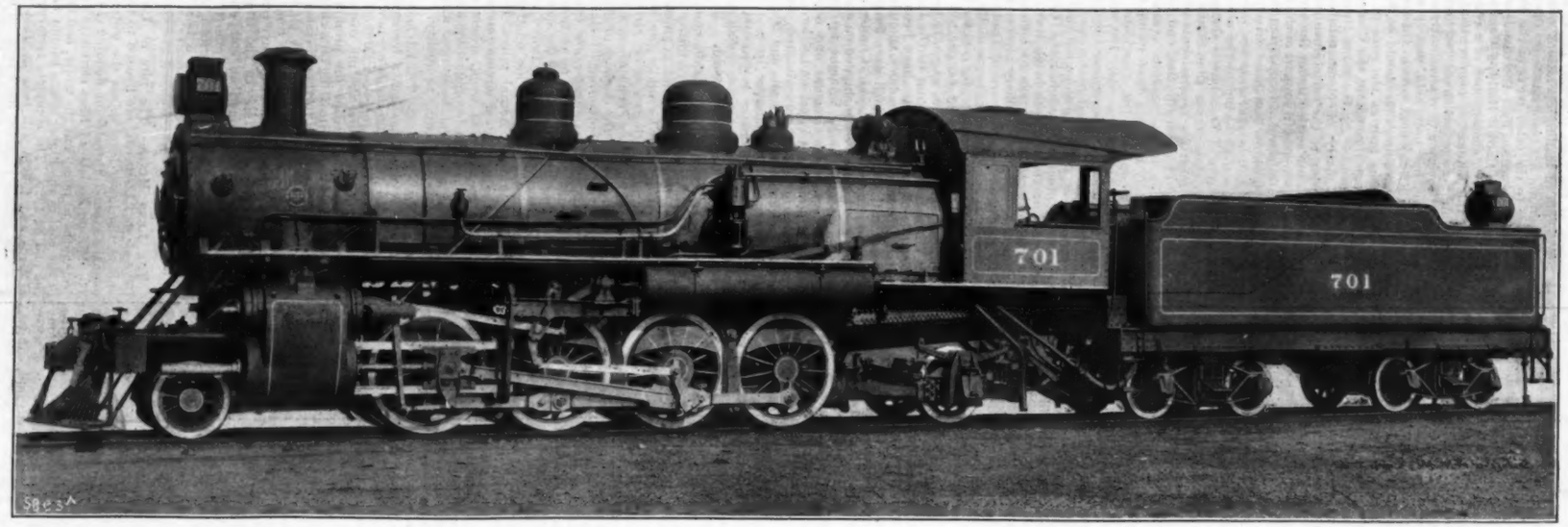


FIG. 1. LOCOMOTIVE FOR THE SOUTH MANCHURIA RAILWAY, KOREA.

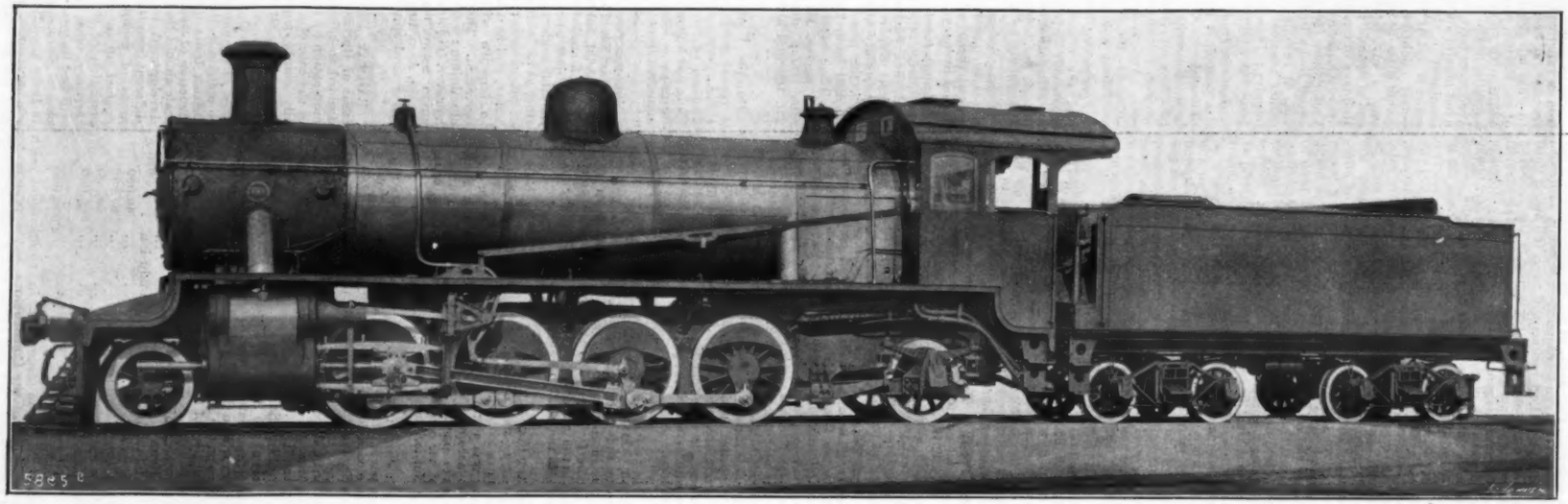


FIG. 2. LOCOMOTIVE FOR THE PEKING-MUKDEN RAILWAY, CHINA.

EXACT DETAILS OF THE PERFORMANCE OF 100 TYPICAL COLLIE

(For Descr

Job No.	District.	Duration of Test, Hours.	Type of Boilers.	Number of Boilers on Plant.	Dimensions of Boilers.	Total Grate Area.	Method of Firing	Number of Tubes in Economiser.	Number of Tubes Wide.	Quality of Coal Burned.	Analysis of Coal Burned. B.T.Us per Lb. (as Fired).	Analysis of Coal Burned. Ash.	Amount of Coal Burned.	Coal Burned per Boiler per Hour.	Coal Burned per Sq. Ft. Grate Area per Hour.	Draught Inches Water Gauge. Chimney Base (or Fan Inlet).	Draught Inches Water Gauge. Side Flues.	Black Smoke.	Temperature Gases. Before Economiser.
						Sq. Ft.						Per Cent.	Lbs.	Lbs.	Lbs.				
1	South Wales	8·00	Lancashire	5	(4) 30′ × 9′ 6″; (1) 30′ × 9′	214·80	Hand	480	10	Anthracite, chiefly dust	13,375	13·6	46,592	1,164·8	27·1	1·65	0·67	None	63
2	South Wales	7·80	Lancashire	1	30′ × 6′	37·50	Hand	None	Nil	Coal from pit face	10,480	17·9	2,720	363·6	9·6	0·37	0·25	Good	62
3	South Wales	7·80	Lancashire	3	30′ × 9′ 3″	122·76	Hand	320	10	Anthracite, mixed quality	14,190	9·4	21,736	965·6	23·6	1·42	0·65	None	59
4	Lancashire	8·00	Lancashire	3	30′ × 9′	117·00	Hand	594	8	Mixed coal	8,665	29·1	18,536	772·3	19·8	0·67	0·26	Medium	60
5	Yorkshire	13·25	Lancashire	6	30′ × 9′	275·76	Hand	544	8	Mixed coal	11,914	13·8	56,580	711·4	15·5	1·00	0·40	Very bad	65
6	Staffs.	7·25	Lancashire	7	30′ × 8′	273·00	Hand	None	Nil	Mixed coal	9,462	14·9	35,840	706·2	18·1	0·58	0·40	Medium	63
7	Yorkshire	8·00	Lancashire	6	30′ × 9′	262·50	Hand	480	10	Mixed coal	9,616	24·5	50,680	1,055·8	24·1	0·61	0·19	Medium	64
8	South Wales	8·00	Lancashire	34	(24) 30′ × 7′; (10) 30′ × 8′	1,145·28	Hand	None	Nil	Fine slack	10,972	21·1	170,943	622·4	15·6	1·01	0·90	Good	65
9	South Wales	8·00	Lancashire	5	Average 30′ × 7′ 6″	162·74	Hand	120	6	Small washed coal	11,564	13·0	17,472	436·8	13·0	0·73	0·34	Good	67
10	Scotland	6·00	3 Lanc., 3 Cornish, 1 Tubular	5	Various (all small)	160·00	Hand	None	Nil	Refuse coal	6,792	23·5	25,536	851·2	26·6	0·77	0·53	Very good	Not ta
11	Staffs.	6·00	Lancashire	7	Average 30′ × 9′	366·75	Hand	None	Nil	Mixed coal	8,456	25·5	48,192	1,076·0	19·2	0·76	0·50	Good	60
12	Lancashire	7·92	Lancashire	5	Average 30′ × 7′	304·00	Hand	None	Nil	Coal from pit face	10,480	15·0	52,052	821·4	21·6	1·30	0·64	Good	Not ta
13	South Wales	8·25	Lancashire	10	(6) 30′ × 8′; (4) 30′ × 8′ 6″	372·00	Hand	880	10	Mixed coal	10,991	23·6	78,624	951·8	25·6	1·27	0·52	Very good	Not ta
14	Lancashire	8·25	Lancashire	4	30′ × 7′ 6″	144·00	Hand	None	Nil	Refuse coal	7,725	15·6	25,312	767·0	21·3	0·45	0·25	Medium	59
15	Yorkshire	8·00	Lancashire	10	(4) 30′ × 9′; (4) 30′ × 7′ 6″; (2) 30′ × 8′	366·725	Hand	640	10	Coal from pit face	12,447	11·9	61,040	763·0	19·7	0·80	0·30	Very bad	62
16	Yorkshire	24·00	Lancashire	5	30′ × 9′	227·50	Hand	None	Nil	Small washed coal	12,079	13·1	62,552	521·2	11·4	0·50	0·30	Medium	57
17	Staffs.	8·25	Lancashire	4	30′ × 8′	144·00	Hand	None	Nil	Mixed coal	8,275	37·8	18,055	564·1	15·3	1·00	0·52	Very good	69
18	Staffs.	8·00	Lancashire	5	(4) 30′ × 8′; (1) 28′ × 7′ 6″	195·50	Hand	None	Nil	Mixed coal	9,645	27·1	35,280	882·0	22·5	0·61	0·40	Fairly good	66
19	Yorkshire	11·50	Lancashire	4	(2) 30′ × 9′; (2) 30′ × 8′ 6″	182·30	Hand	None	Nil	Rough slack	11,726	18·0	33,152	720·7	15·8	0·80	0·40	Medium	71
20	Staffs.	8·33	Lancashire	3	(2) 30′ × 9′ 6″; (1) 30′ × 9′	147·00	Hand	None	Nil	Mixed coal	9,739	11·7	35,616	1,425·2	29·1	0·94	0·27	Very bad	75
21	Staffs.	8·25	Lancashire	2	28′ × 9′	62·50	Coking stokers	None	Nil	Mixed coal	9,509	12·3	27,216	1,649·4	39·9	0·84	0·19	Very bad	70
22	Staffs.	7·50	Lancashire	2	30′ × 8′ 6″	78·00	Hand	192	8	Poor quality fine slack	9,750	16·5	18,592	1,239·0	31·7	1·50	0·45	Good	60
23	Staffs.	8·00	Lancashire	3	(2) 30′ × 6′; (1) 28′ × 7′ 6″	107·75	Hand	None	Nil	Mixed coal	9,900	26·4	17,164	715·1	19·9	0·70	0·50	Good	63
24	Lancashire	8·00	Lancashire	6	30′ × 8′	216·00	Hand	None	Nil	Good quality slack	11,595	15·0	33,592	679·0	18·8	0·75	0·55	Good	63
25	Notts.	8·00	Lancashire	5	30′ × 6′	180·00	Hand	200	10	Mixed slack	9,565	20·1	35,056	876·4	24·3	1·71	0·46	Medium	64
26	Staffs.	7·91	Lancashire	8	Average about 30′ × 7′	325·50	Hand	None	Nil	Coal from pit face	10,310	10·5	59,136	924·5	23·9	0·90	0·60	Bad in times	73
27	Scotland	7·25	Lancashire	3	30′ × 7′ 6″	96·00	Hand	None	Nil	Mixed coal	9,526	16·7	17,034	784·2	24·5	1·00	0·75	Fairly good	64
28	Staffs.	7·80	Lancashire	4	30′ × 8′	182·00	Hand	None	Nil	Mixed coal	8,437	26·1	30,240	1,008·0	23·1	0·74	0·37	Medium	62
29	South Wales	8·00	Lancashire	4	30′ × 8′ 6″	196·00	Hand	320	10	Good quality small coal	12,003	15·7	16,800	525·0	13·4	0·92	0·55	Good	63
30	Lancashire	8·00	Lancashire	4	(2) 30′ × 8′; (2) 28′ × 7′ 6″	144·00	Hand	None	Nil	Good quality small coal	10,863	18·1	19,376	605·5	16·8	0·56	0·44	Bad	64
31	Derbyshire	8·00	Lancashire	8	28′ × 9′	288·00	Hand	None	Nil	Good quality slack	12,750	8·4	41,600	650·0	18·0	0·65	0·35	Medium	60
32	Staffs.	8·00	Lancashire	4	30′ × 9′	144·00	Hand	None	Nil	Mixed coal	9,908	9·5	25,892	799·8	22·2	1·36	0·55	Fair	57
33	Staffs.	9·00	Lancashire	2	30′ × 8′	72·00	Hand	None	Nil	Mixed coal	8,920	38·9	9,849	596·8	16·3	0·62	0·44	Bad	69
34	Staffs.	9·00	Lancashire	4	Average 30′ × 7′ 6″	171·50	Hand	None	Nil	Mixed coal	8,078	36·7	23,744	660·5	15·3	0·55	0·30	Fairly good	62
35	Staffs.	8·00	Lancashire	4	Average 30′ × 8′	194·00	Hand	None	Nil	Mixed coal	8,579	19·8	36,960	924·0	23·8	0·92	0·55	Fair	73
36	Scotland	7·25	Lancashire	3	30′ × 8′	109·50	Hand	None	Nil	Mixed coal	9,639	17·4	17,136	787·8	21·6	0·68	0·43	Good	64
37	South Wales	8·83	Tubular	12	Not ascertained	736·00	Hand	None	Nil	Good quality washed slack	12,171	12·3	73,472	1,145·7	17·3	2·00	0·75	Very good	Not ta
38	Lancashire	7·25	Lancashire	11	Average 30′ × 7′	440·00	Hand	None	Nil	Coal from pit face	11,039	16·3	64,176	804·7	20·3	1·62	0·87	Medium	Not ta
39	Staffs.	8·00	Lancashire	7	28′ × 7′	237·72	Sprinkler stokers	None	Nil	Inferior coal and dust	9,600	17·8	49,346	881·0	25·9	1·10	0·56	Good	675
40	Yorkshire	8·00	Lancashire	3	30′ × 9′	131·76	Hand	None	Nil	Coal from pit face	13,925	6·1	16,520	688·3	15·6	0·25	0·16	Good	679
41	South Wales	7·40	Lancashire	3	30′ × 8′	113·976	Hand	120	6	Good quality small washed coal	12,013	12·8	12,908	580·6	15·3	0·86	0·35	Good	660
42	Scotland	7·38	Lancashire	3	28′ × 7′ 6″	111·40	Hand	None	Nil	Mixed coal	10,635	10·9	17,227	792·0	21·3	0·60	0·40	Bad	662
43	Notts.	8·00	Lancashire	4	31′ × 7′ 6″	196·00	Hand	None	Nil	Mixed coal	9,855	22·6	27,534	860·4	17·6	0·70	0·43	Fairly good	668
44	Staffs.	7·75	Lancashire	3	30′ × 9′	105·00	Hand	None	Nil	Mixed coal	10,150	14·0	17,094	733·2	20·9	0·65	0·36	Medium	656
45	Lancashire	8·50	Lancashire	5	30′ × 7′ 6″	165·00	Hand	None	Nil	Mixed coal	10,200	18·0	29,780	700·0	21·3	0·68	0·35	Medium	660
46	South Wales	8·00	Lancashire	3	(2) 32′ × 8′; (1) 30′ × 8′	108·00	Hand	None	Nil	Anthracite, chiefly dust	13,925	8·1	16,884	703·5	19·5	0·55	0·44	None	669
47	South Wales	8·00	Tubular	4	Not ascertained	130·00	Hand	None	Nil	Fine anthracite	13,500	9·8	15,333	479·0	15·6	0·90	0·25	None	677
48	Warwickshire	8·80	6 Tubular, 3 Land.	9	(L) 30′ × 8′; (T) 8,000 lbs. evap. each	258·00	Hand	None	Nil	Mixed coal	9,970	13·3	56,564	736·8	25·7	0·90	—	Medium	656
49	Staffs.	8·16	Lancashire	6	(3) 30′ × 7′; (3) 28′ × 7′	196·00	Hand	None	Nil	Mixed coal	7,548	15·4	26,908	727·2	22·0	0·53	0·34	Medium	659
50	Derbyshire	8·83	Lancashire	6	(3) 30′ × 9′; (3) 30′ × 8′ 6″	257·16	Hand	None	Nil	Mixed coal	10,567	10·4	61,504	614·7	14·3	0·90	0·50	Very good	668
51	Derbyshire	8·00	Lancashire	6	(4) 30′ × 8′; (2) 30′ × 7′ 6″	209·79	Hand	None	Nil	Mixed coal	10,162	16·8	39,984	833·0	23·9	0·80	0·50	Medium	720
52	Derbyshire	8·00	Lancashire	6	30′ × 8′ 6″	255·96	Hand	None	Nil	Mixed coal	12,172	10·1	48,730	1,015·0	23·6	0·50	0·26	Very bad	708
53	Lancashire	8·00	Lancashire	6	30′ × 7′ 6″	196·00	Hand	None	Nil	Mixed coal	10,030	17·8	34,800	725·0	21·9	0·70	0·36	Medium	665
54	Derbyshire	9·00	Lancashire	6	(2) 30′ × 8′ 6″; (4) 30′ × 7′ 6″	210·00	Hand	None	Nil	Good quality slack	12,690	8·1	40,800	850·0	34·3	0·70	0·40	Fairly good	690
55	Yorkshire	8·25	Lancashire	5	30′ × 8′	180·00	Hand	None	Nil	Mixed coal	10,730	16·8	34,031	825·0	22·9	0·82	0·53	Medium	670
56	Gloucestershire	6·66	Lancashire	9	30′ × 8′	351·00	Hand	None	Nil	Rough small	12,310	11·4	44,800	747·4	19·1	1·08	0·64	Bad	701
57	Derbyshire	8·00	Lancashire	6	30′ × 8′	216·00	Hand	None	Nil	Mixed coal	10,950	16·7	38,849	805·2	23·3	0·80	0·45	Medium	636
58	Lancashire	8·50	Lancashire	4	30′ × 8′ 6″	156·00	Hand	None	Nil	Mixed coal	10,650	17·2	25,840	780·0	19·5	0·75	0·45	Medium	630
59	Lancashire	9·00	Lancashire	6	30′ × 8′	234·00	Hand	None	Nil	Good quality slack	12,100	13·5	45,808	954·3	24·5	0·85	0·51	Good	662
60	Yorkshire	8·83	Lancashire	5	30′ × 8′	218·96	Hand	None	Nil	Peas and slack	10,267	24·2	38,512	827·0	18·90	0·58	0·38	Medium	656
61	Lancashire	8·00	Lancashire	6	30′ × 8′	216·00	Hand	None	Nil	Small slack	10,518	20·2	35,840	746·6	20·7	0·64	0·45	Medium	612
62	Staffs.	7·80	Lancashire	1	28′ × 7′ 6″	31·92	Hand	None	Nil	Good quality slack	11,515	17·7	4,816	643·1	20·1	0·63	0·45	Good	630
63	Yorkshire	10·00	Lancashire	7	30′ × 8′	253·80	Hand	None	Nil	Good quality peas	13,377	8·8	49,616	708·8	21·2	0·58	0·35	Bad	616
64	Staffs.	8·00	Lancashire	3	(1) 28′ × 7′; (1) 27′ × 7′	104·80	Hand	None	Nil	Mixed coal	9,703	14·9	16,520	688·3	19·7	0·66	0·51	Fair	623
65	Lancashire	8·00	Lancashire	2	30′ × 9′	78·00	Hand	192	8	Good quality slack	12,580	12·9	11,452	714·5	18·3	1·00	0·59	Medium	660
66	Staffs.	8·00	Egg-ended (6), Lancashire (2)	8	(15) 32′ × 5′. (L) 27′ × 7′ 6″	313·80	Hand	None	Nil	Mixed coal	9,058	19·5	33,712	526·7	19·8	0·73	0·31	Fair	655
67	South Wales	8·00	Lancashire	6	30′ × 9′	285·48	Coking stokers	960	10	Small slack	11,540	21·83	55,440	1,155·0	24·3	0·60	0·20	Good	686
68	Shropshire	8·41	Lancashire	3	30′ × 8′ 6″	126·00	Hand	None	Nil	Mixed coal	11,357	12·8	16,184	997·1	23·7	0·86	0·50	Good	700
69	Yorkshire	8·00	Lancashire	6	(2) 30′ × 9′; (5) 30′ × 8′	214·50	Hand	None	Nil	Good quality slack	12,935	12·0	26,784	719·6	16·7	1·31	0·47	Bad	686
70	Derbyshire	9·91	Lancashire	9	Average about 28′ × 8′	330·80	Hand	None	Nil	Good quality slack	12,554	8·4	47,713	530·0	15·0	0·80	0·35	Medium	680
71	Scotland	7·83	Lancashire	11	30′ × 8′	395·00	Hand	600	10	Refuse coal	9,460	6·3	143,960	1,671·4	46·7	1·17	0·74	Medium	Not ta
72	Staffs.	8·00	Lancashire	5	30′ × 9′; 28′ × 7′ 6″; (3) 30′ × 8′	162·00	Hand	None	Nil	Mixed coal	9,089	17·4	44,940	1,106·0	30·4	0·72	0·53	Fairly good	661
73	South Wales	6·80	Lancashire	3	30′ × 7′	109·79	Hand	128	8	Good quality nuts	13,331	8·9	9,064	413·5	11·3	0·48	0·31	Good	643
74	South Wales	139·75	Lancashire	2	30′ × 8′	91·00	Hand	None	Nil	Anthracite peas	13,280	8·5	155,708	687·3	10·7	0·38	0·16	None	647
75	Notts.	8·00	Lancashire	5	30′ × 8′	117·00	Hand	160	10	Mixed coal	10,653	13·5	23,972	961·3	24·6	1·71	0·53	Medium	643
76	Derbyshire	7·66	Lancashire	4	(2) 30′ × 8′ 6″; (2) 30′ × 9′ 6″	168·00	Hand	None	Nil	Mixed coal	10,715	14·7	21,056	657·2	16·3	0·89	0·55	Good	653
77	Yorkshire	8·00	Lancashire	9	(3) 30′ × 9′; (3) 30′ × 8′; (3) 30′ × 7′ 6″	340·75	Hand	160	8	Good quality slack	13,853	10·3	83,528	729·4	19·2	0·76	0·53	Bad	646
78	Staffs.	6·00	Lancashire	2	30′ × 7′	73·84	Hand	None	Nil	Mixed coal	9,560	34·2	5,670	324·4	9·6	0·66	0·39	Medium	638
79	Lancashire	8·00	Lancashire	3	30′ × 9′	117·00	Hand	192	8	Mixed coal	9,783	20·7	23,197	966·5	24·8	0·93	0·55	Medium	676
80	Scotland	8·00	Lancashire	7	Average 30′ × 9′	273·00	Sprinkler stokers	None	Nil	Mixed coal	10,900	20·3	57,499	1,030·3	26·4	1·60	0·74	Very good	673
81	Yorkshire	8·75	Lancashire	10	30′ × 8′ 6″	390·00	Hand	None	Nil	Mixed coal	11,326	16·8	80,616	1,127·0	25·9	1·20	1·00	Medium	697
82	Yorkshire	10·00	Tubular (4), Lancashire (3)	7	Not ascertained with certainty	372·00	Hand	None	Nil	Good quality slack	12,950	8·7	113,008	1,614·4	30·4	1·85	0·70	Bad	707
83	Yorkshire	13·33	Lancashire	11	30′ × 8′	474·00	Hand	None	Nil	Small slack	12,091	14·8	126,336	931·4	21·6	1·60	0·50	Bad	726
84	Notts.	7·80	Lancashire	7	30′ × 8′ 6″	393·00	Hand	None	Nil	Mixed coal	9,873	22·9	46,704	889·6	17·7	0·70	0·40	Medium	649
85	Lancashire	8·00	Lancashire	4	(2) 30′ × 8′; (2) 30′ × 7′ 6″	144·00	Hand	None	Nil	Good quality slack	13,223	14·7	34,920	776·7	21·6	0·75	0·60	Good	654
86	Yorkshire	9·00	Lancashire	2	30′ × 8′	72·00	Hand	None	Nil	Mixed coal	10,649	20·4	15,888	771·6	21·4	0·50	0·40	Medium	695
87	Notts.	8·00	Lancashire	7	30′ × 8′	252·00	Hand	None	Nil	Good quality slack	13,630	7·9	49,840	890·0	24·7	0·75	0·45	Medium	653
88	South Wales	9·25	Lancashire (9), Tubular (4)	13	(L) 30′ × 9′. (T) 10,000 lbs. per hour	589·63	Hand	None	Nil	Good quality slack	12,864	13·4	116,680	966·6	21·3	1·68	0·60	Good	677
89	South Wales	8·00	Lancashire	8	30′ × 8′	288·00	Hand	None	Nil	Good quality coal	13,065	13·0	88,832	873·3	24·2	1·20	0·51	Medium	Not ta
90	Scotland	7·50	Egg-ended	3	Average 30′ × 8′ 6″	70·00	Hand	None	Nil	Mixed coal	10,355	12·5	11,200	497·7	21·4	0·46	—	Bad	649
91	Scotland	7·33	Lancashire	6	30′ × 8′	237·80	Hand	None	Nil	Mixed coal	9,974	10·4	48,372	1,097·1	27·8	1·26	0·87	Medium	681
92	South Wales	7·00	Lancashire	5	30′ × 8′	114·30	Hand	None	Nil	Good quality coal	13,890	14·9	36,304	1,094·6	47·8	0·71	0·59	None	Not ta
93	Staffs.	8·25	Lancashire	4	(3) 30′ × 9′ 6″; (3) 30′ × 10′	330·43	Hand	None	Nil	Mixed coal	10,737	9·6	43,388	1,311·6	33·7	0·95	0·60	Good	704
94	Lancashire	7·80	Lancashire	6	30′ × 8′	216·00	Hand	None	Nil	Mixed coal	11,115	12·2	31,136	691·9	19·3	0·63	0·20	Good	Not ta
95	Staffs.	7·50	Lancashire	7	(3) 30′ × 8′; (4) 28′ × 7′	253·84	Sprinkler stokers	None	Nil	Mixed coal	10,060	12·3	51,520	981·3	27·2	1·20	0·70	Good	Not ta
96	Notts.	8·00	Lancashire	4	30′ × 8′	144·00	Hand	None	Nil	Mixed coal	9,247	15·7	44,800	1,400·0	38·8	1·35	0·89	Medium	673
97	Staffs.	8·00	Egg-ended	7	30′ × 9′	168·00	Hand	None	Nil	Mixed coal	9,477	14·8	31,564	564·0	23·5	0·92	—	Good	657
98	Staffs.	8·00	Egg-ended	4	Average 32′ × 8′ 6″	112·00	Hand	None	Nil	Good quality coal	12,520	13·3	19,040	630·0	21·0	1·00	—	Medium	650
99	Yorkshire	9·80	Egg-ended	9	32′ × 8′ 6″	243·00	Hand	None	Nil	Good quality coal	12,335	14·1	52,640	618·7	22·8	0·90	—	Medium	707
100	Yorkshire	10·75	Egg-ended	8	32′ × 8′ 6″	234·00	Hand	None	Nil	Good quality coal	12,285	11·5	86,000	651·1	22·2	1·06	—	Medium	1,024

AVERAGE FIGURES FOR THE ABOVE 100 TYPI

		9·49	87·7 per cent. Lanc.	5·7	The Lanc. boilers only average about 30′ × 8′ 6″.	217·6	5 per cent. mechanical 95 per cent. hand	See above	See above. Very mixed. Cannot be expressed as an average	10,500	15·5	39,815	721·5	13·9	0·95	0·60	Can be expressed as "medium."	646

AVERAGE FIGURES FOR 250 TYPICAL STEAM BOILER PL

		9·43	93·5 per cent. Lanc.	4·9	The Lanc. boilers only average rather less than 30′ × 8′.	152·6	24 per cent. mechanical 76 per cent. hand	Not given	Very mixed. Cannot be expressed as an average	11,822	11·5	30,131	796·8	20·9	0·89	0·60	Can be expressed as "medium."	680

STEAM BOILER PLANTS (GREAT BRITAIN). By D. BROWNLIE, B.Sc. Hons. (Lond.), F.C.S.

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...ge No. in Text.	Total Water Evaporated	Water Evaporated per Boiler per Hour.	Temperature of Feed Water. Before Economiser.	Temperature of Feed Water. After Economiser.	Percentage Saving Due to Economiser.	Analysis of Boiler Feed Water as going into Boilers. Degree Permanent Hardness.	Analysis of Boiler Feed Water as going into Boilers. Degree Temporary Hardness.	Steam Pressure, Lbs. per Sq. In. Gauge.	Temperature of Saturated Steam.	Temperature of Superheat.	Amount of Steam or Power Used as Auxiliary to the Production of Steam. Percentage of Total Steam Output of Plant.	Brief Description of Steam Jet or other Apparatus Consuming Auxiliary Steam.	Water Evaporated per Lb. of Coal.	Water from and at 212 Deg. Evaporated per Lb. of Coal.	Water from and at 212 Deg. Evaporated per 10,000,000 B.T.Us.	Efficiency of Plant. Total Net Working Efficiency of Plant after Deducting Steam or Power Used Auxiliary to the Production of Steam.	Efficiency of Boilers Only.	Efficiency of Economisers Only.	Efficiency of Superheaters Only.	Load Check Test (One Week Approximate). Duration of Test.	Amount of Coal Burned.	Total Water Evaporated.	Water Evaporated per Lb. of Coal.	Approximate Annual Coal Bill.	Remarks
	Lbs.	Gallons.	Deg. F.	Deg. F.					Deg. F.	Deg. F.			Lbs.	Lbs.	Lbs.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Hours.	Tons.	Gallons.		Tons.	
100	375,254	938·1	82	226	14·4	6·0	2·0	134	357·7	327·0	3·97	(a)	8·05	9·52	717·1	71·84	86·86	10·74	5·48	168·30	379·90	630,900	7·29	19,000	(1)
...ation	16,171	215·6	36	Nil	Nil	3·0	1·0	73	318·5	Nil	Nil	None	5·94	7·24	690·8	66·80	66·80	Nil	Nil	36·00	3·1873	3,800	5·39	600	
100	180,795	803·5	74	171	8·3	6·0	1·0	151	366·2	326·0	5·17	(b)	8·32	9·93	701·7	69·39	63·09	6·74	2·15	168·00	242·40	383,765	7·06	12,100	(2)
100	103,058	429·4	68	289	18·0	4·0	0·0	98	336·3	Nil	8·60	(c)	5·86	6·50	780·1	66·30	59·80	13·00	Nil	149·25	73·55	90,690	5·80	4,000	
100	414,330	921·9	149	271	11·4	9·5	2·0	110	344·1	Nil	Nil	None	7·33	8·10	679·8	65·90	58·30	7·60	Nil	156·50	236·65	302,170	7·39	13,000	
100	250,869	415·1	175	Nil	Nil	15·0	6·0	67	313·6	Nil	Nil	None	5·87	6·29	664·7	64·30	64·30	Nil	Nil	160·00	270·80	363,300	5·98	14,800	
100	304,364	634·1	142	257	10·7	13·0	1·0	88	329·8	Nil	5·75	(a)	6·00	6·65	691·5	63·17	59·71	7·31	Nil	167·75	283·40	307,020	6·28	18,000	(3)
100	1,132,436	417·1	163	Nil	Nil	7·0	2·0	58	305·6	Nil	Nil	None	6·62	7·13	649·8	63·10	63·10	Nil	Nil	168·00	1,261·05	1,819,422	6·00	70,000	
100	117,726	294·3	131	187	2·4	2·0	0·0	62	299·8	Nil	Nil	None	6·73	7·49	647·7	62·65	61·10	1·55	Nil	149·00	83·34	113,980	6·05	8,000	
100	90,600	301·3	39	Nil	Nil	4·0	1·0	86	328·4	Nil	Nil	None	3·54	4·31	634·8	61·37	61·37	Nil	Nil		Not carried out			12,580	(4)
100	223,263	526·8	186	Nil	Nil	11·0	0·0	98	336·6	270·0	Nil	None	4·89	5·22	617·3	61·30	59·65	Nil	1·65	168·00	231·1625	367,992	5·84	16,000	
100	351,164	832·6	200	Nil	Nil	9·0	1·0	61	308·3	Nil	Nil	None	6·36	6·63	633·0	61·13	61·12	Nil	Nil	167·88	304·00	415,161	6·09	16,750	
100	480,060	585·5	101	241	12·2	3·0	0·0	68	314·4	405·0	Nil	None	8·72	6·61	601·4	60·27	50·40	7·41	2·46	170·00	695·15	777,600	5·73	31,000	
100	126,703	383·9	162	Nil	Nil	14·0	1·0	57	304·7	Nil	Nil	None	5·00	5·36	695·4	59·90	59·90	Nil	Nil	168·00	110·30	34,930	5·06	3,750	
100	446,908	586·6	161	253	9·7	13·0	4·0	70	316·1	Nil	3·18	(a)	7·32	7·93	637·2	59·76	56·22	3·54	Nil	167·50	361·00	561,500	5·98	17,880	
100	406,380	338·6	110	Nil	Nil	9·0	2·0	80	333·9	Nil	Nil	None	6·49	7·40	612·6	59·50	59·50	Nil	Nil	168·00	354·95	228,930	6·43	8,000	
100	77,046	333·4	60	Nil	Nil	11·0	2·0	49	296·8	Nil	Nil	None	4·26	5·06	610·2	59·02	59·02	Nil	Nil	168·00	137·14	119,620	4·30	6,500	
100	173,196	433·2	60	Nil	Nil	10·0	2·0	56	303·8	Nil	Nil	None	4·91	5·84	606·5	58·49	58·48	Nil	Nil	168·75	236·675	257,740	4·93	12,300	
100	214,380	466·0	161	Nil	Nil	5·0	0·0	118	348·9	Nil	Nil	None	6·46	7·07	603·6	58·60	58·60	Nil	Nil	157·95	167·95	276,960	6·69	8,000	
100	190,116	760·7	150	Nil	Nil	6·0	5·0	80	323·9	Nil	Nil	None	5·53	5·86	602·3	58·34	58·34	Nil	Nil	168·00	324·475	342,397	5·31	11,000	
100	140,060	648·7	161	Nil	Nil	7·0	2·0	80	323·9	541·0	2·96	(r)	5·14	5·55	563·9	58·21	55·93	Nil	3·06	168·00	196·95	180,280	5·13	6,000	
100	95,022	633·5	125	228	9·5	10·5	0·5	150	365·7	420·0	2·5	(a)	5·11	5·83	596·9	57·06	52·26	5·40	1·69	169·00	126·00	147,000	5·25	6,500	
100	80,540	356·4	60	Nil	Nil	10·0	5·0	52	299·6	Nil	Nil	None	4·96	5·91	596·9	57·76	57·76	Nil	Nil	170·00	144·96	183,150	5·84	7,800	
100	201,900	430·6	175	Nil	Nil	4·0	0·0	94	333·9	401·0	Nil	None	5·71	6·13	598·6	57·39	55·63	Nil	1·96	169·50	258·00	319,970	5·89	13,350	
100	181,100	452·7	144	188	4·1	13·0	2·0	65	311·0	Nil	Nil	None	5·16	5·89	594·8	57·58	55·15	2·43	Nil		Not carried out			10,000	(5)
100	232,723	525·8	157	Nil	Nil	4·5	3·5	68	314·4	Nil	Nil	None	5·62	6·13	594·5	57·47	57·47	Nil	Nil	168·00	294·30	439,578	6·50	14,750	
100	82,437	379·0	89	Nil	Nil	24·0	1·0	92	332·6	Nil	Nil	None	4·84	5·65	593·4	57·33	57·33	Nil	Nil	168·00	139·10	139,005	4·46	6,180	
100	127,800	456·6	147	Nil	Nil	8·0	0·0	63	314·4	Nil	Nil	None	4·55	5·00	592·5	57·30	57·30	Nil	Nil	168·00	127·75	136,200	4·89	7,000	
100	103,282	323·7	79	239	15·9	3·0	1·0	111	344·7	Nil	2·5	(a)	6·14	7·23	601·5	57·02	49·10	9·26	Nil	168·00	113·00	174,118	6·87	6,480	
100	134,853	358·9	186	Nil	Nil	10·0	3·0	65	311·9	378·0	Nil	None	5·93	6·27	588·0	56·87	56·87	Nil	Nil	169·00	130·45	186,380	5·83	8,000	
100	280,800	483·9	180	Nil	Nil	10·0	4·0	75	320·1	Nil	Nil	None	6·98	7·44	583·6	56·90	56·50	Nil	Nil	168·00	224·00	280,500	6·98	11,500	
100	152,742	396·7	63	Nil	Nil	9·0	1·5	93	333·2	Nil	Nil	None	4·84	5·06	591·4	56·37	56·37	Nil	Nil	174·00	215·95	238,490	4·70	10,800	
100	41,561	389·9	88	Nil	Nil	11·0	3·0	56	303·7	Nil	Nil	None	4·35	5·19	581·8	56·27	56·27	Nil	Nil	165·00	50·34	53,600	4·16	2,980	
100	101,011	380·6	146	Nil	Nil	9·0	2·0	73	317·7	Nil	Nil	None	4·25	4·68	579·5	56·12	56·12	Nil	Nil	151·00	74·00	71,940	4·34	3,780	
100	163,715	409·3	145	Nil	Nil	6·0	2·5	142	361·7	Nil	Nil	None	4·43	4·61	580·8	55·86	55·86	Nil	Nil	165·75	224·45	213,047	4·24	11,300	
100	86,581	398·8	146	Nil	Nil	2·0	2·5	65	311·9	Nil	Nil	None	5·06	5·56	576·3	55·75	55·75	Nil	Nil	166·25	68·50	128,650	6·47	4,480	
100	429,740	716·8	146	Nil	Nil	7·5	1·0	132	356·6	Nil	Nil	None	6·28	6·73	553·1	55·38	55·38	Nil	Nil		Not carried out			22,000	(6)
100	396,478	489·5	140	Nil	Nil	10·0	1·0	68	313·7	Nil	Nil	None	5·71	6·31	571·6	55·30	55·30	Nil	Nil	168·75	476·4	571,770	5·35	33,500	
100	349,300	445·0	150	Nil	Nil	10·0	2·0	60	307·4	Nil	7·5	(a)	5·05	5·47	569·6	55·15	55·15	Nil	Nil	168·00	399·5	443,267	4·94	30,000	
100	100,830	420·0	49	Nil	Nil	14·0	2·0	86	328·4	Nil	Nil	None	6·10	7·37	570·2	55·10	55·10	Nil	Nil	168·00	110·12	153,286	6·21	6,000	
100	79,974	359·7	141	182	3·9	4·0	0·0	64	311·0	Nil	Nil	None	6·19	6·62	570·2	55·10	52·95	2·15	Nil	57·75	34·00	31,270	5·81	4,800	
100	94,656	435·2	145	Nil	Nil	10·0	0·0	68	314·4	Nil	Nil	None	5·49	6·06	568·8	55·04	55·04	Nil	Nil	170·25	130·59	143,632	4·91	6,800	
100	138,090	421·9	129	Nil	Nil	11·0	3·0	74	319·3	Nil	Nil	None	4·90	5·50	567·2	53·90	53·90	Nil	Nil		Not carried out			7,000	(7)
100	89,627	361·3	113	Nil	Nil	11·5	0·5	148	364·7	444·0	8·0	(r)	5·20	5·99	590·1	55·80	57·12	Nil	2·43	168·50	117·55	125,580	4·77	6,300	
100	151,725	356·9	145	Nil	Nil	12·0	1·0	66	311·9	Nil	Nil	None	5·10	5·60	549·0	53·25	53·25	Nil	Nil	168·00	95·25	106,680	5·00	5,330	
100	107,870	448·3	53	Nil	Nil	5·0	1·0	81	324·7	Nil	7·76	(g)	6·37	7·05	597·2	53·23	57·73	Nil	Nil	168·00	103·1375	46,630	6·34	6,000	
100	93,700	293·6	44	Nil	Nil	6·0	2·0	154	352·3	Nil	Nil	None	6·15	7·49	550·7	53·25	53·25	Nil	Nil	168·00	96·95	150,280	6·92	9,000	
100	277,912	363·2	176	Nil	Nil	9·0	0·0	96	335·3	380·3	Nil	None	4·93	5·31	532·6	52·74	51·80	Nil	1·24	168·50	308·987	397,380	5·74	16,000	
100	100,015	270·6	137	Nil	Nil	22·0	0·0	55	302·6	Nil	Nil	None	3·71	4·11	541·9	52·70	52·70	Nil	Nil	167·50	196·922	193,963	4·23	10,000	
100	124,880	356·1	161	Nil	Nil	12·0	2·0	67	329·1	Nil	8·8	(h)	5·79	6·31	597·1	52·60	57·70	Nil	Nil	168·50	194·77	215,720	5·31	9,500	
100	308,216	435·8	84	Nil	Nil	12·0	3·0	69	315·3	Nil	2·5	(a)	5·33	6·34	614·0	52·10	53·40	Nil	Nil	169·50	344·95	419,500	5·43	17,500	
100	253,180	610·8	46	Nil	Nil	9·0	8·0	103	339·8	Nil	10·3	(w)	6·01	7·29	598·8	52·00	57·96	Nil	Nil	168·00	413·95	493,700	5·23	20,000	
100	179,230	377·5	150	Nil	Nil	16·0	2·0	68	314·4	Nil	Nil	None	5·15	5·86	537·6	51·67	51·67	Nil	Nil	168·50	122·62	143,667	5·23	6,500	
100	346,840	514·2	130	Nil	Nil	12·0	3·0	80	323·9	Nil	Nil	None	6·06	6·74	536·3	51·81	51·81	Nil	Nil	168·00	133·00	182,200	6·12	6,750	
100	190,264	437·2	165	Nil	Nil	14·0	2·0	73	318·5	Nil	Nil	None	5·30	5·74	535·4	51·75	51·75	Nil	Nil	167·25	118·15	139,800	5·43	6,300	
100	289,288	432·5	140	Nil	Nil	8·0	1·0	97	336·9	366·9	Nil	None	5·78	6·27	527·4	51·53	51·00	Nil	0·53	167·50	480·25	630,263	6·30	23,000	
100	306,772	430·8	160	Nil	Nil	12·0	4·0	75	320·1	Nil	Nil	None	5·36	5·81	530·6	50·93	50·93	Nil	Nil	169·50	143·25	172,965	5·40	8,000	
100	134,268	305·2	169	Nil	Nil	15·0	1·0	72	317·7	Nil	Nil	None	5·20	5·53	533·9	50·87	50·87	Nil	Nil	170·25	99·85	119,940	5·35	6,250	
100	388,331	500·0	127	Nil	Nil	4·0	5·0	76	320·9	Nil	3·4	(u)	5·85	6·57	543·9	50·78	52·96	Nil	Nil	168·00	392·80	467,280	5·31	21,698	
100	165,504	420·1	186	Nil	Nil	6·0	5·0	60	307·4	Nil	Nil	None	5·08	5·58	534·0	50·90	50·90	Nil	Nil	169·00	227·85	249,700	4·89	13,330	
100	174,586	383·7	151	Nil	Nil	11·0	3·0	73	318·5	377·0	Nil	None	4·87	5·34	507·4	50·84	49·11	Nil	1·43	169·00	236·06	264,030	5·06	11,000	
100	25,722	343·9	118	Nil	Nil	12·0	4·0	47	294·7	Nil	Nil	None	5·34	6·00	531·0	50·41	50·41	Nil	Nil	154·00	19·50	23,230	5·31	986	
100	319,230	456·0	166	Nil	Nil	9·0	5·0	64	311·0	Nil	Nil	None	6·43	6·93	518·0	50·20	50·20	Nil	Nil	168·00	179·90	260,800	6·47	9,000	
100	83,580	296·0	136	Nil	Nil	7·0	0·0	44	291·5	Nil	Nil	None	4·15	4·89	473·0	50·04	50·04	Nil	Nil	168·40	133·30	94,163	3·41	6,180	
100	63,745	298·4	91	275	16·5	2·5	0·5	96	336·3	Nil	Nil	None	5·57	6·49	515·9	50·00	41·70	8·30	Nil		Not carried out			3,000	(8)
100	143,152	223·7	143	Nil	Nil	8·5	0·0	58	306·6	Nil	Nil	None	4·25	4·69	517·7	49·88	49·88	Nil	Nil	169·00	204·10	163,375	3·84	10,300	
100	280,016	622·9	169	266	4·82	4·5	1·0	127	353·9	531·6	8·64	(o)	5·39	5·84	506·0	49·35	44·61	4·65	4·34	168·00	354·70	509,760	6·41	17,900	
100	79,778	491·5	162	Nil	Nil	10·0	5·0	68	314·4	449·0	Nil	None	4·92	5·33	473·4	48·91	45·89	Nil	3·03	167·50	142·23	169,843	5·30	7,500	
100	173,271	433·1	140	Nil	Nil	2·5	0·0	95	334·6	Nil	6·4	(r)	6·05	6·70	534·9	48·44	51·78	Nil	Nil	169·00	193·69	241,670	5·58	9,500	
100	321,860	316·1	182	Nil	Nil	10·0	0·0	63	319·2	Nil	Nil	None	5·91	6·30	503·6	48·40	48·40	Nil	Nil	167·25	314·30	397,278	6·19	12,000	
100	361,299	652·0	84	126	6·2	2·5	0·0	126	358·6	Nil	Nil	None	3·90	4·74	501·0	48·31	45·29	3·02	Nil	166·50	1,110·65	1,093,000	4·11	55,500	
100	198,632	471·6	116	Nil	Nil	4·0	3·0	114	346·5	Nil	2·0	(q)	4·26	4·66	501·6	48·09	49·07	Nil	Nil	168·00	296·30	270,640	4·07	16,000	
100	49,200	253·3	157	175	1·7	2·0	0·0	58	303·7	430·0	Nil	None	6·10	6·60	495·0	48·00	46·23	0·84	0·93	117·00	67·60	76,510	5·06	4,000	
100	1,013,966	317·3	63	Nil	Nil	6·0	1·0	62	309·2	Nil	15·35	(s)	6·51	7·73	583·4	47·79	56·58	Nil	Nil	Carried out as "day a test"				4,000	(9)
100	134,680	486·9	144	188	4·1	13·0	2·0	64	311·0	Nil	5·9	(s)	5·06	5·56	583·8	47·67	48·84	3·13	Nil	176·00	114·65	137,440	5·25	6,000	
100	106,400	347·2	179	Nil	Nil	16·0	5·0	68	329·8	Nil	2·7	(t)	5·06	5·44	504·9	47·60	48·80	Nil	Nil	168·00	102·60	132,630	5·77	8,500	
100	309,409	429·7	127	170	4·0	12·0	1·0	70	316·1	376·0	7·9	(u)	5·69	6·61	526·6	47·60	44·30	6·4	0·73	167·90	409·88	572,100	6·23	22,000	
100	23,286	139·2	89	Nil	Nil	11·0	3·0	35	280·9	Nil	Nil	None	3·93	4·64	485·3	46·95	46·96	Nil	Nil	166·00	62·75	46,340	3·91	2,700	
100	101,370	434·9	87	231	12·9	4·0	0·0	96	335·3	Nil	6·06	(v)	4·39	5·13	534·3	48·73	44·24	6·89	Nil	169·00	143·76	130,725	4·71	7,500	
100	274,831	490·7	102	Nil	Nil	13·0	0·0	63	309·2	Nil	3·6	(w)	4·76	5·45	500·0	46·66	45·40	Nil	Nil	192·00	484·50	495,800	4·78	23,300	
100	497,940	567·9	162	Nil	Nil	9·0	0·0	94	333·9	Nil	1·0	(x)	5·06	5·51	456·4	44·53	46·99	Nil	Nil	168·25	886·48	713,940	5·43	30,000	
100	680,960	973·8	105	Nil	Nil	20·0	12·0	130	350·0	Nil	10·3	(v)	6·02	6·94	543·6	46·47	51·80	Nil	Nil	168·00	689·55	789,100	4·91	35,000	
100	982,290	510·4	192	Nil	Nil	14·0	1·0	95	327·6	Nil	Nil	None	5·48	5·73	478·0	46·20	46·20	Nil	Nil	169·50	393·80	518,940	6·04	20,000	
100	199,780	380·5	153	Nil	Nil	14·0	2·0	75	320·1	Nil	Nil	None	4·27	4·68	474·0	45·90	45·90	Nil	Nil	170·50	249·35	261,340	4·83	13,000	
100	139,484	404·6	178	Nil	Nil	3·0	0·0	95	334·6	473·0	Nil	None	5·19	5·57	458·8	45·63	44·13	Nil	1·50	168·00	142·75	155,450	4·66	9,160	
100	70,112	389·5	206	Nil	Nil	13·0	1·0	93	333·2	Nil	4·8	(q)	5·06	5·26	493·9	45·60	47·90	Nil	Nil	167·50	81·525	108,460	5·95	6,880	
100	389,136	480·6	155	Nil	Nil	14·0	3·0	75	320·1	Nil	Nil	None	5·40	5·88	465·9	45·25	45·29	Nil	Nil	168·00	262·00	330,030	5·56	13,750	
100	603,005	501·4	121	Nil	Nil	7·5	1·0	130	350·0	442·0	Nil	None	5·17	5·89	457·8	44·79	44·29	Nil	0·50	170·00	794·00	940,150	5·28	42,000	
100	306,227	478·4	171	Nil	Nil	6·0	2·0	75	320·1	Nil	Nil	None	5·48	5·91	453·3	43·69	43·69	Nil	Nil	165·00	346·40	469,012	6·04	17,500	
100	66,725	199·7	96	Nil	Nil	19·0	0·0	34	279·6	Nil	Nil	None	4·01	4·57	441·3	43·71	43·71	Nil	Nil	166·75	73·80	68,380	4·18	3,680	
...tions	188,987	429·5	160	Nil	Nil	6·0	0·0	66	312·7	362·0	Nil	None	3·92	4·25	436·5	43·67	41·20	Nil	1·47	96·00	193·15	179,547	4·17	12,500	
100	204,921	585·2	67	Nil	Nil	6·0	2·0	86	328·4	Nil	6·4	(aa)	5·34	6·36	467·3	43·33	45·21	Nil	Nil	168·00	248·08	307,930	5·04	13,400	
100	195,386	564·7	168	Nil	Nil	19·0	2·0	97	335·9	Nil	Nil	None	4·30	4·65	433·0	42·10	42·10	Nil	Nil	167·75	219·45	251,708	5·13	11,000	
100	136,124	302·5	137	Nil	Nil	12·0	0·0	50	297·8	Nil	Nil	None	4·37	4·83	434·5	42·10	42·10	Nil	Nil	169·50	199·00	210,440	4·72	10,815	
100	226,022	434·5	163	Nil	Nil	26·0	2·0	67	313·6	397·6	15·1	(aa)	4·43	4·78	476·6	40·77	46·11	Nil	1·89	168·00	600·76	607,760	4·84	31,000	
100	158,600	489·4	195	Nil	Nil	12·5	1·5	64	311·0	Nil	Nil	None	3·49	3·66	396·8	38·32	38·32	Nil	Nil	168·00	176·55	184,170	4·66	9,000	
100	103,514	189·0	133	Nil	Nil	6·0	1·5	53	300·8	Nil	Nil	None	3·35	3·61	380·9	38·01	38·01	Nil	Nil	170·08	205·25	189,675	3·67	10,000	
100	79,360	248·0	165	Nil	Nil	15·0	3·0	47	294·7	Nil	Nil	None	4·00	4·31	353·6	34·06	34·06	Nil	Nil	164·25	75·00	66,300	3·95	4,000	
100	208,610	243·9	134	Nil	Nil	13·0	0·0	50	297·8	Nil	Nil	None	3·96	4·18	338·9	33·80	33·80	Nil	Nil	168·00	216·50	203,310	4·19	11,000	
100	211,320	245·9	143	Nil	Nil	5·0	0·0	54	301·8	Nil	Nil	None	3·77	4·13	336·1	33·50	33·50	Nil	Nil	163·90	138·60	114,230	3·67	7,000	

...LIERY STEAM BOILER PLANTS (GREAT BRITAIN).

78	256,900	393·1	137	154	1·6	9·5	2·0	86	328·4	350·0	1·8	(cc)	5·44	6·07	575·1	55·52	55·62	0·90	0·62	about 168·00	235·2	273,990	5·19	11,900	

...PRESENTING 27 DIFFERENT INDUSTRIES (GREAT BRITAIN).

76	197,776	824·3	115	153	7·1	Not given		89	330·5	346·5	2·4	(ee)	4·86	7·46	631·0	60·09	56·71	4·35	0·51	167·50	128·25	194,435	4·42	6,500	

WORKS OF THE NEWALL ENGINEERING COMPANY, WALTHAMSTOW.

(*For Description, see Page* 104.)

FIG. 1. SCREW GAUGE SECTION.

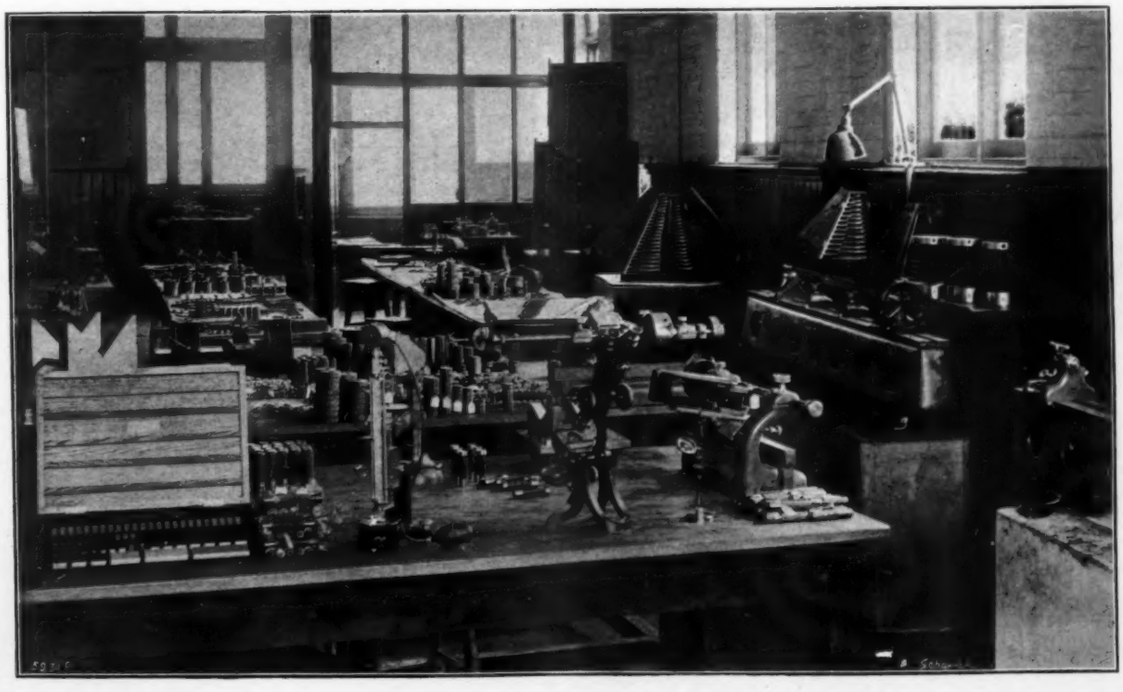


FIG. 2. CHIEF TEST ROOM.

(*To face page* 104.)

WORKS OF THE NEWALL ENGINEERING COMPANY, WALTHAMSTOW.

(*For Description see Page* 104.)

FIG. 3. GENERAL VIEW OF MACHINE SHOP.

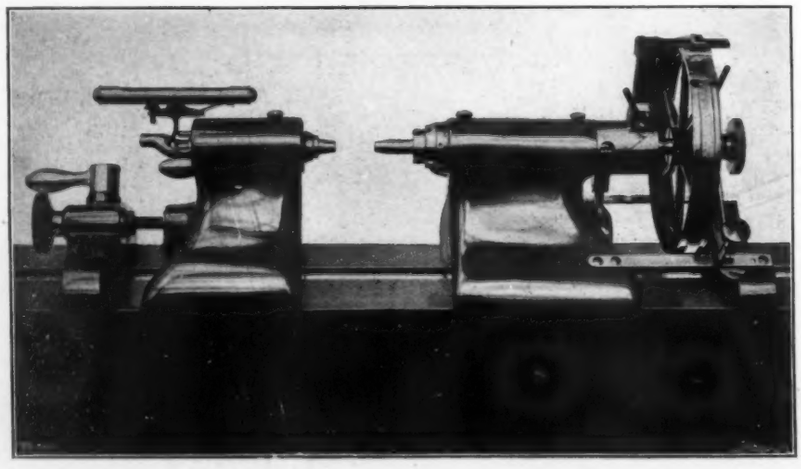


FIG. 4. NEWALL MEASURING MACHINE.

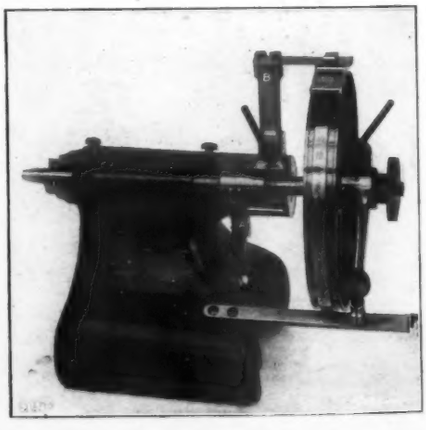
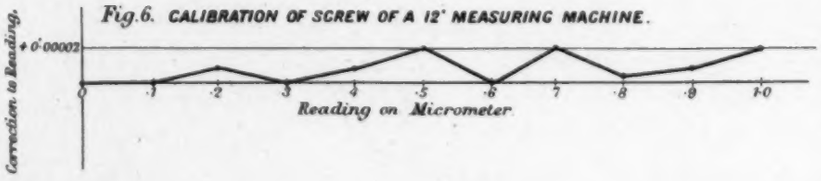
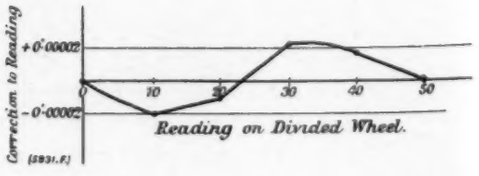


FIG. 5. ADJUSTABLE VERNIER ARM.

Fig. 6. **CALIBRATION OF SCREW OF A 12" MEASURING MACHINE.**





THE WORKS OF BRITISH FORGINGS, LIMITED, TORONTO.

(*For Description, see Page* 106.)

FIG. 1. MELTING HOUSE, WITH SIX-TON HEROULT ELECTRIC FURNACES.

FIG. 2. TEEMING A HEAT FROM AN ELECTRIC FURNACE.

FIG. 3. PNEUMATIC HAMMER FOR BREAKING CROP ENDS FROM BILLETS.

(*To face page* 106.)

THE WORKS OF BRITISH FORGINGS, LIMITED, TORONTO.

(*For Description see Page* 106.)

FIG. 4. ONE OF THE TRANSFORMER AND SWITCH ROOMS.

FIG. 6. FORGING SHOP WITH OIL-FIRED BILLET FURNACES AND HYDRAULIC FORGING PRESSES.

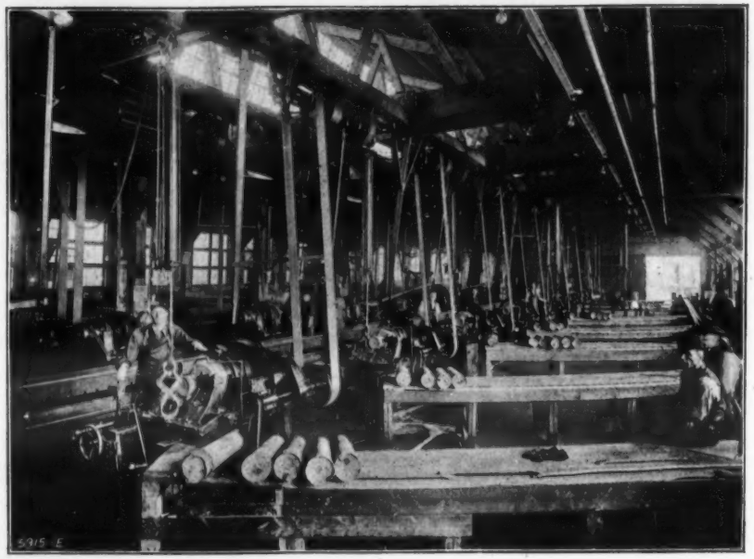


FIG. 5. CUTTING AND BREAKING SHOP, WITH MACHINES FOR GROOVING INGOTS.

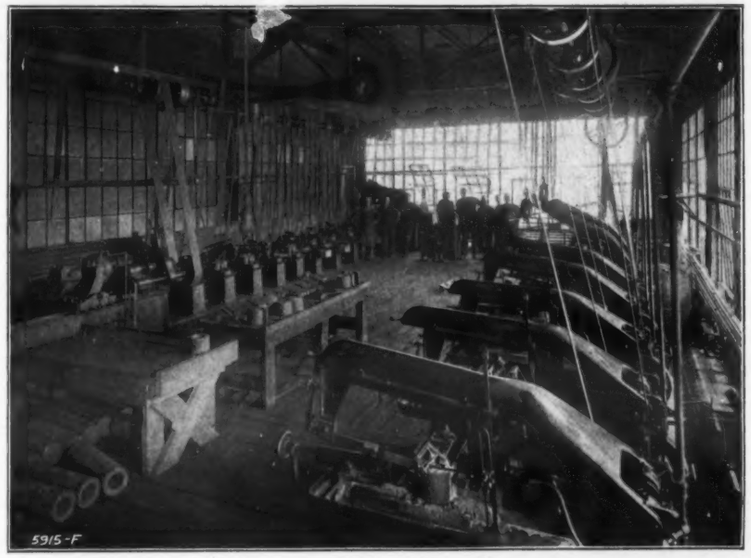


FIG. 7. HACK-SAWS FOR SAWING OFF TEST PIECES FROM FORGINGS.

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ENGINEERING.

FRIDAY, JULY 25, 1919.

"LIEU-RATES" AND "TIME AND A BIT."

On the subject of the remuneration of labour there remain still in force many of the provisions and extensions of practice introduced under the stress of war conditions, the effects of which are the opposite of conducive to increased efficiency; they place us in an unfavourable position as manufacturers for competing in the world's markets. These conditions are such that neither the men nor their unions will make the slightest move towards any alteration. The severe stress of war conditions naturally, and quite early in the rush to produce munitions, led to competition amongst employers to secure the services of the limited number of available workers so as to increase the productivity of their plant, to man the new machines and increased equipment installed, and to assist towards keeping their promises in regard to deliveries of the weapons of war so urgently called for by the many authorities, often competing amongst themselves for delivery. Not only was there competition to get men, but with the certainty of employment on application, there was the difficulty of retaining the men who might be induced to start. Rapidly the workers gauged the situation, and unless assured that their remuneration was above the standard, they moved elsewhere to better their conditions. To such an extent finally was this the case, that, none too early, legislation had to be introduced to limit such tendencies.

As a means to increased output, and specially applicable to repetition work, payment by results was earnestly advocated by the authorities, and in response extended adoption of the system took place. Such adoption was facilitated by the Munitions Act, and various agreements to which the Trades Unions subscribed.

In regard to most systems of payments by result, such as piece work, there will be no denying that the following two facts stand out quite clearly. Firstly, that with repetition work, the system can be applied most readily, and will show a great improvement on time work, and, secondly, that with such work, if the product remains substantially the same, even a slightly high price at the introduction of the system will lead with remarkable rapidity to earnings many multiples of the time rate of wages previous to the introduction of the system.

As is well-known, such earnings in the past have given rise to the practice of the cutting of rates. During the war two tendencies operated and should be noted. Due to the fact that many shops were engaged on a type of product of which they previously had little or no experience, and also to the lack of experienced piece price or rate-fixers to cope satisfactorily with the fixing of prices or times for the mass of work being turned out, prices which were exceedingly high were far from uncommon. The cutting of prices, a practice, the only excuse for which is ignorance, was practically impossible in this connection, because of the general difficulties with labour, the strong position of the labour organisations, the sympathetic appeal system that was introduced by the authorities to reduce labour discontent, either real or imaginary, and on account of the favourable terms that were offered to employers for the contracts placed on a fixed price basis, albeit the "time and line" system was quite generally adopted for new work, or in the case of firms of insufficient experience, to quote on a fixed-price basis.

In what position, then, was a manufacturer whose work was of such a nature that payment by results could not readily be applied to a considerable proportion of it? How could he keep his men, when in an adjacent works, repetition work, and payment by results, with the high earnings generally accruing from such a state, was the rule?

There can be little contention that in all shops there is a considerable portion of the work that lends itself quite readily to system of payment by results, although on work of a non-repetition character the prices or times must be generously estimated if earnings comparable with those earned on repetition work, as has already been explained, are to be possible. Supposing this fact be recognised, there still remains a proportion of the workers who cannot readily be put upon payment by results, and there are the periods of time when the general payment by result workers cannot work on other than the time system of remuneration.

Such a state of affairs exists to a certain extent in shipbuilding and in lesser measure in marine engineering. To meet these conditions, the "Lieu-Rate" or "Time and a Bit" system was in vogue, principally in shipyards, even prior to the war. As its name implies, "Lieu-Rate" is an enhanced time rate given in lieu of piece work, as, for instance, on a new job, a price for which it is felt cannot be fixed. It may require very particular skill, and on this account it may well be desired to allocate to such work the best available workers, who normally, in all probability, make large earnings on piece work or a similar system. An arrangement is then made to the end that, either these men will be paid during the time they are so engaged at the same percentage over their time earnings as they have been receiving for a given period previously, or else on a fixed percentage over their time rates, called "time and a bit," generally time and a half. To expect workers under the conditions experienced during the war period to revert to plain time rates when on such work, would have caused them to seek the more remunerative piece work elsewhere; such was the demand for labour. There were shops in which no effort was made to work a system of payment by results. "Lieu work," or "Time and a Bit" offered the path of least resistance, giving high earnings and being thus favourably regarded by the men and their union officials. It was, in fact, simply a very much higher time rate than the district or the average rate, and so, on that account, not open to the objection lodged against payment by results. The efforts on the part of the management necessary to fix satisfactory and equitable piece rates or bonus times were not required.

The number of jobs in any shop that can be regarded as incapable of estimating with a view to fixing a price or bonus times, is in proportion to the number of ratefixers appointed for this work, coupled with the experience available, and is further dependent upon the degree of organisation of management of the work.

With a sufficient number of ratefixers possessing the requisite experience, the amount of work which cannot be priced may be said to be extremely small, provided the work is so arranged and organised that delays for want of material are infrequent, the appliances are adequate, and that men are not hustled from one incomplete job to another, and so on. The question arises as to whether such an organisation as is necessary, with a large staff of rate-fixers—and in many classes of work quite a large staff will be required to assess prices for all work being undertaken—will give value for the increased on-cost resulting? If present-day practice be referred to, the answer would be in the negative, but the opinion is gradually gaining ground that competition in the future will force a more ready realisation that the experiment must be boldly faced in the endeavour to reduce the selling price of our manufactures. In the United States of America this necessity is perhaps more generally recognised. If the alternative is "lieu-work" or "time and a bit," little trepidation in taking the step need be felt. These systems, however, are extremely expensive in wages cost per unit of output.

There remain a number of cases where the fixing of prices or bonus time is most difficult, as for instance, where the actual time required for the work is to some extent without the control of the management or the men concerned—such work, as, for instance, testing, where the testing time is dependent largely upon the requirement of an

inspector, and is not capable of definite specification. Testing work can sometimes quite conveniently be made part of the contract of the erectors or fitters or can be a separate contract; although in such work the tendency under these conditions would be to hide defects, which at all costs should be brought immediately to light. Work of this nature could be paid for at a rate depending upon the rate earned on previous work, although the objections to such a system arising from a tendency to prolong the operation in question, &c., are obvious, and need not be enlarged upon. The question of the payment for work of this nature in a payment-by-results shop is not capable of ready solution, and merits the closest study, although only a subsidiary issue of the main subject of "Lieu Rates" and "Time and a Bit."

Such systems have been so extended during the war, and have in many quarters obtained such a firm footing that with competitive conditions again returning, the firmest stand must be taken completely to eliminate them. The path of least resistance in such matters can only lead in one direction—that of high labour costs and selling prices. We have previously urged, when dealing with payments by results, and can only again most strongly emphasise, the necessity for definite knowledge of all conditions before fixing prices or basis times. Men of high standing and technical qualifications must be trained and then placed in positions of authority to deal efficiently with the very complex subject of the fixing of piece prices, bonus times and allowances. By such a course only can we effect the change in some of our industries from the haphazard, rule-of-thumb methods of control of these matters of the past, to the more progressive and virile grip consequent upon putting into practice, in regard to remuneration in proportion to effort, the results of thorough and detailed investigation.

MERCHANT SHIPBUILDING.

ACCORDING to statistics just issued by Lloyd's Register, there were 782 merchant vessels, with a total gross tonnage of 2,524,050, under construction in the United Kingdom at the end of June last. These figures constitute a record, the tonnage being some 12 per cent. greater than the previous record of 2,254,845 tons building at the end of the March quarter, and 39 per cent. greater than the figure for the June quarter of last year, which was 1,815,013 tons. Compared with the highest pre-war figure of 2,063,694 tons, reached in March, 1913, the present tonnage shows an improvement of over 22 per cent., but the satisfaction that would otherwise be gained from this comparison is tempered by the knowledge that our need for shipping is now far greater than ever before. As it is, we can only hope that the present high figures will be increased. In all other countries of the world, excluding Germany, for which country figures are not yet available, 1,744 vessels, making 5,493,717 tons in all, were under construction on June 30 last, and of this amount no less than 994 vessels, aggregating 3,874,143 tons, were building in the United States. Although the tonnage building in that country has declined from 4,185,523 in March to the figure just given, it is still more than 26 times the corresponding figure for June, 1914, at which time there were only 45 ships, totalling 148,515 tons, in hand. Japanese shipbuilding has also developed considerably during the war period. The ships building in Japanese yards now number 63, with a total tonnage of 282,060, as compared with 18 ships, making 91,510 tons, in June, 1914; in this case the increase amounts to over 200 per cent. These figures are significant enough, but the situation will, perhaps, be even clearer if we point out that just before the war nearly 55 per cent. of the total tonnage under construction in the world was building in British yards, whereas, at the present time, the proportion is but little more than 30 per cent.; the latter figure would be even smaller if we were able to include the work of German yards. We recommend these figures to the careful consideration of British labour leaders and others interested in the future of industry and commerce in this country.

The British Dominions are now building 209 vessels, which account for another 346,453 tons of the shipping under construction abroad, and Italy now comes third on the list of foreign countries taken in order of magnitude of shipbuilding work in hand. The figures for Italy, which are 96 vessels, with a total tonnage of 271,620, show a notable increase over those for previous quarters, a fact which is due to the inclusion of Trieste, for the first time, as an Italian port. The only other countries with tonnages under construction exceeding 100,000 are Holland, Spain, and France, the figures for these countries being 219,332 tons (88 ships), 118,854 tons (40 ships), and 109,615 tons (38 ships), respectively. Holland has nearly doubled its shipbuilding work since June, 1914, when there were 51 vessels, with an aggregate tonnage of 116,137, building in Dutch yards, while Spain, at that time had only two vessels under construction, making 4,429 tons together. France, on the other hand, is now building less than half the tonnage she had in hand just before the war.

Referring again to the merchant shipbuilding work of this country during the quarter under review, we notice a considerable improvement in the number and tonnage of vessels launched, and also in new work commenced. In the June quarter 206 ships, making 527,891 tons were launched, and 183 ships, making 659,980 tons, were laid down. The corresponding figures for the March quarter were 74 vessels (205,316 tons) launched and 103 vessels (425,128 tons) commenced. The vessels now constructing include a number of large ships, 28 steamers of over 10,000 tons being in hand; no vessel, however, exceeds 25,000 tons. Ferro-concrete barges and motor vessels building at the end of the quarter amounted together to 22,064 tons—less than 1 per cent. of the total. Rather more than half of the increased tonnage under construction is being built on the Clyde. Glasgow and Greenock yards between them, are now building 138,844 tons more than at the end of the March quarter—an increase of over 18 per cent. The actual number of vessels in hand in this district is now 253, and the total tonnage amounts to 893,467, while in March last the figures were 184 vessels and 754,623 tons. Newcastle comes next in order of importance, the increase in this district amounting to 64,362 tons, which is nearly 15 per cent. more than in March. Newcastle is now building 100 ships, with a total tonnage of 498,294, as compared with 91 ships, and 433,932 tons, in March. Belfast has 44 vessels, totalling 320,800 tons now in hand—a slight increase on the corresponding figures for the previous quarter. The position at Sunderland is somewhat similar, the current figures for this district being 63 vessels of 269,018 tons in the aggregate. The tonnage under construction in the Middlesbrough district, at the end of June, was 163,280, comprising 47 vessels, the tonnage being 10 per cent. greater than in March. The work in hand at Hartlepool now amounts to 19 ships, making 76,450 tons, which is practically the same as the previous quarter, but at Liverpool a very substantial increase has to be recorded. At the end of last month this port was building 31 ships, with an aggregate tonnage of 58,395, as compared with 20 ships, making 35,585 tons, in March; the tonnage increase is thus about 64 per cent. At Hull also the tonnage building has increased, by something like 20 per cent., from 44,825 in March to 53,259 in June, the latter figure comprising 87 vessels. Barrow is the only district which shows a decline in merchant shipbuilding during the quarter, the tonnage having fallen from 31,295 to 28,865, and the number of ships from 13 to 6.

On the whole, however, there appears to have been an unprecedented degree of activity in the shipbuilding industry during the period under consideration, and the urgent necessity for maintaining, or increasing, this activity by every possible means should be obvious to all. In view of these circumstances, the effect of any prolonged shortage in the supply of coal can only be contemplated with dismay.

THE SOCIETY OF CHEMICAL INDUSTRY.

MEETINGS of the Chemical Engineering Group of the Society of Chemical Industry were held in the Salters Company's Hall, St. Swithin's Lane, E.C., on the 16th inst. A number of papers were read of which the majority were concerned with questions of steam raising. The subject was in general referred to as bearing on chemical factories, but the greater part of the information given had a wider bearing. We propose to give a *résumé* of two of the more important papers.

WASTE HEAT BOILERS AND PULVERISED FUEL.

The first contribution, supplied by Capt. C. J. Goodwin, A.M.Inst.C.E., dealt with waste-heat boilers and pulverised fuel. In view of the fuel situation, in which this country now finds itself, any matter bearing on economy in steam raising and metallurgical processes has become of importance. Captain Goodwin said that the gas and coke-oven industries were probably the principal users of fuel in the chemical industry, and that it seemed surprising so little had been done to utilise fully the available heat in suitable cases. The objection might be raised that in gas works and with coke-oven plant working regeneratively, if more heat was taken out of the gases their temperature would be insufficient to maintain a proper draught. This objection could be overcome by the use of induced draught and given suitable conditions for utilising the steam, waste-heat boilers should be quite remunerative.

A case was quoted of a waste-heat boiler designed by the Bonecourt Waste Heat Boiler Company, Limited, and ordered as a trial installation for a standard set of continuous vertical retorts working under natural draught. The gases entered the boiler at 700 deg. C., and left at 300 deg. C. A better utilization of the gases would be possible if induced draught were employed. A boiler working with the waste gases from a single retort setting, gave 500 lb. of steam per hour at 100-lb. pressure, so that a gas works, comprising, say, 60 retorts could raise 7,500 lb. of steam an hour from and at 100 deg. C. in return for a capital outlay of about 4,000*l.*, and with relatively small operating costs.

In the case of a gas engine, tests made by the Institution of Civil Engineers, showed that at full load about 38 per cent. of the total available heat in the gas was exhausted into the atmosphere and about 30 per cent. lost in the water-jacket and by radiation. Taking a 1,000-h.p. engine, the full load steam production based on 60 per cent. thermal boiler efficiency was 2,250 lb. of steam an hour, equivalent to about 280 lb. of coal. Allowing for interest, depreciation, &c., and taking coal at 35*s.* a ton, and 3,500 working hours per annum, for the gas engine, the net saving would be about 450*l.* a year on a capital outlay of 600*l.* to 800*l.* Appreciable additional saving could be effected by using the pre-heated water from the engine jacket as boiler feed. Captain Goodwin then referred to the Still engine,* pointing out that the principles it involved might be looked on as a logical extension of the method of using gas-engine exhaust in waste-heat boilers. He thought, however, that in chemical works a waste-heat boiler would usually be preferred. In such places high-pressure steam was the exception and quantities of hot water were frequently required.

Waste gases from many processes contained appreciable amounts of dust, which was a frequent source of trouble in waste-heat boilers of the ordinary water-tube or fire-tube type, the dust settling on the water-tubes and brickwork containing them, or tending to choke up the fire-tubes. The obvious remedy was to increase the velocity of the gases sufficiently to prevent deposition of dust, but in the usual types of boilers this was only possible at the expense of efficiency. The Bonecourt Company had overcome the difficulty by using an inner metal tube with the end closed towards the direction of flow. The diameter of the inner tube was calculated to give the desired velocity in any given case. The inner tube also eliminated the relatively inactive central core of hot gas and enabled fire-tubes of greater diameter to be used. Captain Goodwin had himself devised a method of breaking-up this hot core of gas by means of a spiral placed inside the tube at intervals of about 6 ft., the spiral being made with a pitch decreasing in the direction of the gas flow.

* See ENGINEERING, vol. cvii, p. 708.

Turning to the question of pulverised fuel, Captain Goodwin pointed out that the modern tendency in regard to fuel economy aimed at the prevention of the use of any coal in a raw state. Distillation of coal was, however, a long way from being universal, and was not usually applied in the case of inferior or small-grade fuel. The use of pulverised fuel would undoubtedly be greatly extended in the present transition period, owing to the immediate saving in fuel that could be effected, but its ultimate economic value and application lay rather in the possibilities of using inferior fuels, and of such coal and coal dust as had so far been considered commercially useless.

Practically any quality of fuel could be burnt successfully, and the choice of fuel was not entirely governed by its cost per unit of calorific value. The quality rather than the quantity of ash was of the greatest importance, also the sulphur content, which should not, normally, exceed 1 per cent., though as much as 4 per cent. and more had been found permissible under boilers. Bituminous coal, with 28 per cent. ash, and averaging 6 per cent. sulphur, had actually been burnt in locomotives. Fuel with 30 per cent. of volatile matter and 6 per cent. to 10 per cent. ash, would be ideal. The excess air required with hand-fired grates was 100 per cent. to 200 per cent., and about 50 per cent. with mechanical stokers. With pulverised fuel about 20 per cent. was practically standard, and considerably less could be used with careful control. The carbon dioxide content of the flue gases when using the theoretical amount of air, was 20·7 per cent., and the loss in efficiency when this was reduced to 11 per cent., was only about 5 per cent. Further reduction in the CO_2 content entailed rapidly-increasing loss in efficiency, the loss being as high as 25 per cent. of the total fuel when the CO_2 content fell to about 6 per cent., as in hand-firing practice. With powdered fuel, 15 per cent. CO_2 represented good average practice. With inferior fuels containing considerable percentages of ash, the flame temperature and efficiency were materially reduced, and particular attention had to be paid to the quality and properties of the ash and to its action on the brickwork.

For pulverising, 95 per cent. through 100 mesh and 82 per cent. to 85 per cent. through 200 mesh was now practically standard. The average fineness was 600 mesh or less, and the surface exposed to oxidation on combustion was about 26 sq. ft. per pound, so that combustion was almost instantaneous. Pulverised coal weighed between 38 lb. and 45 lb. per cubic foot and had an angle of repose of 15 deg. to 20 deg. The moisture content in the fuel was usually reduced to at most 1 per cent. before use. It was quite possible to burn powdered fuel containing 4 per cent. of moisture, but it seemed well established that apart from inconveniences, such as the possibility of freezing and agglomeration during storage, the loss of efficiency due to vaporising and superheating the extra moisture content in the furnace counterbalanced the fuel required for drying. The overall cost of drying was, however, greater than the value of the heat lost in vaporising the moisture in the coal and drying was mainly justified by the necessity of this operation for satisfactory pulverising, transportation, and storage in large plants. If 2 per cent. of moisture was removed from coal by drying, it was on the average only equivalent to about 25 per cent. of the moisture contained in the air used for combustion, and for small self-contained plants the cost of drying was not usually justified. In some recent tests carried out with an "Aero" self-contained pulverising unit of 5,000 lb. per hour capacity, it was found that coal containing 4 per cent. of moisture of which ½ per cent. was combined moisture, was delivered to the collector with only ½ per cent. of total moisture, showing that all the free moisture had been absorbed by the air during pulverisation. In a further test wet coal containing 16·4 per cent. of moisture was delivered with only 4·4 per cent. of moisture. Such results as this could, of course, only be obtained when using air separation, as moist coal would choke up any screening device.

Of the ash content of pulverised coal, about 65 per cent. could be collected as fused or semi-fused slag. The remainder probably went up the chimney in the form of a very fine white powder which seemed to cause no inconvenience in large towns. Pulverising cost from 1*s.* 6*d.* per ton for a 10-ton per hour plant to 2*s.* per ton for a 2-ton plant, taking power cost at about 0·7*d.* per kw.-hour. Labour would represent about 4*d.* in the former case and 9*d.* in the latter, two men being necessary with either plant. Including handling and conveying, the average figure for preparing pulverised coal for a large plant would be about 2*s.* 6*d.* a ton. Against this a fuel economy of 15 per cent. to 30 per cent. might be set. The cost of installation was about the same as for a producer gas plant. A British quotation of April of this year for a plant to burn 20,000 tons of pulverised coal a year was 14,500*l.* The total operating cost including interest, rates, &c., worked out at from 3*s.* 6*d.* to 4*s.* a ton, exclusive of the cost of the fuel.

Low-Grade Fuel.

A paper by Mr. P. Parrish, entitled "The Production of Steam for Low-Grade Fuel and a Chemical Works Power Plant," dealt with steam raising from coke breeze. Mr. Parrish began by stating that coke breeze was a very indefinite term and while some gas engineers would regard all material passing through a ¾-in. screen as coke breeze, others would consider such material, or at least that passing a ½-in. screen, as coke dust. Whatever the definition, the quality of coke breeze had been materially modified during the last few years of the war, owing to the increased ash content of the coal. The work to which he wished to refer were situated adjacent to a gas works and quantities of coke breeze were immediately to hand. The material supplied to the works during the last three months had an average ash content of 20·9 per cent. and a moisture content of 14·2 per cent. On an average screening test 25·74 per cent. of the material passed an ½-in. screen, 43·05 per cent. a ¼-in. screen, 71·66 per cent. a $\frac{1}{8}$-in. screen, and 83·72 per cent. a $\frac{1}{16}$-in screen.

The furnaces used for this fuel were of the "Crosthwaite" type having an air supply to the fuel bed through passages in the fire bars, which communicated with the bed by means of fan-shaped openings. An air blast was maintained by a steam nozzle at the front end of the air passages. Further passages through the fire-bars carried a secondary supply of air which entered the combustion area at the end of the furnace without passing through the fuel bed. This secondary air supply was controlled by the chimney draught. The correct regulation of the air was a matter of some difficulty, and had to be controlled according to the size and quality of the fuel, the porosity of the fuel bed and its condition as regarded clinker. It was sometimes assumed that the best results were obtained by admitting such a quantity of primary air as led to the formation of carbon monoxide, which could be subsequently burned to carbon dioxide. It had been suggested that this was the best way to ensure a high CO_2 content in the waste gases. Mr. Parrish's experience did not confirm this view in connection with the combustion of coke breeze in forced-draught furnaces. Combustion would be very seriously retarded if attempt were made to restrict the supply of primary air to such proportions as would lead to the formation of CO. The resistance offered by the fuel bed was such as to necessitate the introduction of such a quantity of primary air as promoted very largely the production of CO_2.

Analyses of the gases above the fuel bed when the latter was reasonably clean and under full blast showed results as high as 16·5 per cent. of CO_2 and 6·4 per cent. of CO. Tests of the gases leaving the main flue, however, showed that such a composition was not maintained for long and that dilution arose. The dilution was traced to the introduction of excess secondary air due to the imperfect fit of the ash-pit doors and to the absence of adequate provision for adjusting the quantity of secondary air. Steps taken to remedy these defects gave greatly improved results. Experience suggested that the depth of the fuel bed should be about 6 in. and that it would be an advantage if the outer primary air ports were adjustable. Systematic and judicious clinkering played an important part in securing efficient results. It was usual to clinker the fires twice each eight-hour shift. The necessity for quick cleaning and recharging was evident. It was important that the air tubes should be kept clean. Fine dust passed through the perforations in the bars and had to be removed periodically.

The question of the productive capacity of the boilers when using low-grade fuel was important. There was a distinct relationship between thermal efficiency and productive capacity, and a Lancashire boiler, say, which was capable of evaporating 600 gallons of water an hour with best steam coal, was incapable of being worked with coke breeze, at a maximum thermal efficiency, above an evaporative capacity of 400 gallons an hour. The author had found that the grate as sometimes installed by forced-draught specialists was too long to admit of maximum thermal efficiency. By reducing the grate length by about 20 per cent. the temperature of the waste gases was reduced from 310 deg. C. to 240 deg. C., a lesser quantity of fuel was consumed, the capacity of the boilers was unimpaired and the chimney draught was not prejudicially affected. The original arrangement merely led to the combustion of extra fuel and an increase in temperature of waste gases, very little extra heat being transmitted to the water, largely due to the absence of adequate heating surface.

The importance of frequent and systematic cleaning of the side and bottom flues of the boilers could not be too strongly urged. This affected the question of the entrainment of drift (fine dust and grit) and its possible discharge from the chimney shafts. This entrainment by the products of combustion was a direct function of the velocity of the gases. If the speed exceeded 6 ft. to 8 ft. per second trouble from drift was inevitable. Clearly as the flues began to accumulate dust their cross-sectional areas decreased with a consequent increase of velocity. It had been found necessary to clean the side and bottom flues each six weeks. Mr. Parrish compared the cost of steam raising in the plant with which he was dealing with the costs which had been published for several Government factories. To obtain comparative figures the cost of coal at the various Government factories instead of being taken at a flat rate of 1*l.* a ton, as had been done in the published figures, were reduced by him to the cost of similar coal at the works with which he was dealing. On this basis the coal cost worked out at about 33*s.* a ton. The coke breeze cost about 13*s.* a ton. Allowing for maintenance, labour, &c., the cost of steam raising at the coke-breeze plant showed a saving of 21 per cent. as compared with the cheapest Government coal plant and over 50 per cent. as compared with the most expensive.

NOTES.

Films of Metals in Glow Lamps.

In our issue of November 9, 1917, we noticed an investigation of the deposits of metals and also salts, formed on the inside walls of incandescence lamps by the sublimation of the metallic filaments or of the salt coatings previously imparted to them. A further communication on these researches has been presented by Professor W. Reinders and by Mr. L. Hamburger, of the Eindhoven Laboratory of Messrs. Philips' Lamp Works, to the Amsterdam Akademie van Wetenschappen (Proceedings, vol. xx, pages 1135 to 1154). The metallic particles, shot off from the hot filaments, are condensed on the glass walls; there is very little reflection unless the walls be really hot. The very thin deposits produced may appear homogeneous (amorphous-vitreous) when examined by the ultra-microscope, or show (or develop) a structure, and any colours of the deposits may be due to the film thickness and structure or be characteristic of the substance. The metals investigated were mounted as wires in bulbs after the manner of tungsten filaments; the same bulb was used to enclose two lamps, the second one serving for producing a protective coating on the deposit formed by heating the wires of the first lamp. This coating consists of salt or fluorspar, and was added because the coating of Canada balsam, first used to prevent atmospheric corrosion of the deposits, did not quite protect the films; none of these coatings proved perfectly indifferent,

however. The bulb was so arranged further that a branch from it could be cooled in liquid air, in order to form deposits at low temperatures. It was found that, as to the appearance of the films, two classes of metals may be distinguished, refractory metals and metals melting at moderately high temperatures. The former, tungsten, molybdenum, platinum, nickel, iron, and carbon (carbon is only mentioned in one line) gave amorphous-vitreous films, practically devoid of any structure. The metals of the other group, silver, gold, magnesium, zinc, cadmium, yielded films in which separate particles, ultramicrons, were distinguishable. Deposited on the cooled glass, these films also appeared amorphous, but a structure developed on heating the glass and film. A structure also developed in tungsten and the other metals, but only on heating the deposit up to near the melting point. As the thickness of the silver film increased, the colour changed from yellow to red and blue; on heating the film, the colours changed again in the opposite order. With silver this colour change set in already at 130 deg. C.; it seemed to be due to the amorphous form, not to the crystalline grouping, and would thus be characteristic of the metal. Gold turned from pink to red, violet-blue, green, yellow and finally to gold-yellow, as the film thickened; magnesium, &c., especially also copper, showed similar colour changes. The films of the refractory metals and of carbon were black or grey. The electric resistance of the films was also determined after the method recently used by E. Weber and Oosterhuis. In the case of gold the steel-blue film, produced on glass cooled in liquid air, had first a very high resistance, amounting to thousands of ohms, but the resistance decreased to 250 ohms, *e.g.*, as the film slowly assumed room temperature. The resistance generally diminished in the course of time, particularly when the films were exposed to the air (from 119 ohms to 72 ohms in 4 hours), but also in the vacuum. The resistance changes are evidently connected with the development of a structure.

Solutions of Metals in Ammonia.

Whilst salts and other compounds and some elements can be dissolved in water and various solvents without undergoing any chemical change, and can be recrystallised from these solutions, it is largely assumed that metals cannot be dissolved in this sense, except in other metals. That anhydrous ammonia will dissolve the alkali metals, when heated with them in sealed tubes, was in fact observed by Weyl in 1864, however. Palmaer obtained coloured solutions apparently of metals, blue in the case of alkali metals, green for lead, red for tin, by electrolysing solutions of organic salts in liquid ammonia, which boils at $-33{\cdot}5$ deg. C. Ruff and Geisel, 1906, prepared by the direct action of liquid ammonia on the alkali metals solutions of the deep copper lustre of certain beetle wings; diluted, these solutions appeared dark blue, and the crystalline metal was reobtained by evaporating the ammonia; one atom of sodium required 5·87 molecules of ammonia for dissolution. Real solutions seemed to be formed, not substituted ammonium compounds of the formula NH_2Na, as had been suggested; there is, it will be remembered, some evidence for the existence of a metal like compound NH_4, ammonium, although the body has never been isolated except momentarily. On the other hand, in sealed tubes substitution products of ammonia, of the type NH_2Na, are also formed. Studying, in 1907, the electrolytic conductivity of the blue solutions in ammonia of the alkali metals, C. A. Kraus (Massachusetts Institute of Technology) came to the conclusion that the neutral metal dissociated into a positive metal ion and a negative electron. Although much interest was at that time taken in the electrolytic properties and dissociation of solutions in non-aqueous solvents, Kraus and Franklin seem alone to have studied these particular solutions. A few years ago, G. E. Gibson and W. L. Argo took up the optical examination of these solutions. It was peculiar that lithium, sodium, potassium, magnesium and calcium should all give diluted blue solutions in ammonia. Gibson and Argo (Journal of the American Chemical Society, September, 1918, pages 1327 to 1361) therefore investigated the absorption spectra by modifying the spectrophotometer of Martens and Grünbaum, who sent part of a beam of light through a cell containing the solvent and part through a cell containing the solution. To simplify the apparatus Gibson and Argo adopted a differential method, without directly determining the absorption of the ammonia itself; this is regrettable, the ammonia might play the chief part in the phenomena. They found that all the metals mentioned, with the possible exception of calcium, gave identically the same absorption in ammonia, and very similar absorption spectra (though different from those in ammonia) in methylamine. They argue that the absorption might be due: (*a*) To unionised molecules or atoms of the metal; (*b*) to unsolvated electrons; (*c*) to solvated electrons, *i.e.*, electrons surrounded by and migrating with molecules of the solvent. Kraus had taken view (*a*); Gibson and Argo consider that one might prefer (*b*); when they calculated the conductivity observed on this assumption, however, they arrived at impossible values for the number of electrons and the conductivity. Hence they decide in favour of (*c*). The experiments have to be performed at low temperatures, of course, and contamination of the solutions is very difficult to avoid. The alkali metals oxidise immediately on exposure to air, and in that case the blue solutions fade rapidly; this trouble was almost unavoidable when they worked with ethylamine. It is to be hoped that the difficult research will be continued.

THE BRITISH SCIENTIFIC PRODUCTS EXHIBITION.

(*Continued from page* 76.)

Proceeding with our notices of electric exhibits at the Exhibition, we will first deal with those of Messrs. Creed and Co., Telegraph Works, Croydon, who give demonstrations with two notable exhibits. The one, the High-Speed Printing Telegraph, of Mr. F. G. Creed, is well-known. Morse code is used, a large number of stations can be worked on one line, and automatic retransmission is facilitated. The Wheatstone tape is perforated by the Kleinschmidt keyboard at a rate of 600 words per minute, the Wheatstone transmitter is motor-driven for up to 250 words per minute. The Creed perforating receiver reproduces an exact replica of the sending tape; the incoming line signals actuate a relay, the tongue of which controls the valves of pneumatic engines, and the received perforated slip is fed into the printer, which reproduces the message in Roman letters on a paper slip, gummed to telegraph forms, at the rate of 120 words per minute; the received perforated tape may be used several times and re-transmitted by Wheatstone. The other instrument, the Creed Stentorphone, is a novelty with which Mr. H. A. Gaydon is connected. The stentorphone reproduces gramophone needle-cut records on an adjustable intensity scale with superior quality of tone. The volume of sound is controlled by admitting into a sound box a stream of air, from a rotary compressor driven by an electric motor. The stream of air issuing from the sound box is controlled by a valve, which is, in its turn, under the control of the gramophone needle. The valve consists of two small grids of aluminium superposed upon one another; when playing the stream of air is set into vibration, and the sudden expansion of the air after passing through the valve gives the great volume of sound. By means of a special air-control valve, operated by hand, the air can be diverted into another channel in order to cut out the sound-box; a modulator further admits of toning the volume of sound down from a roar, audible at $\frac{1}{4}$ mile distance, to a whisper.

The construction of the complete Gyro unit of Messrs. Elliott Brothers, for compasses and precision instruments, which spins continuously at 20,000 r.p.m. and a peripheral speed of 430 ft. per second or 300 miles p.h., being driven by three-phase currents of 333 cycles, at 120 volts, 0·45 ampere in each phase, has required extreme care and superior materials. The spindle, all one with the body of the rotor, is of the Laval type; the balls for the bearings had to be specially selected. The hardened steel sleeves on the taper ends of the rotor spindle have a taper of 0·006 in. in a length of 0·375 in. and the top thrust works up against a steel ball and a spring. The stator had to be wound by hand and to be placed dead in the centre of the gyro case. Among the other exhibits, galvanometers and accessories, photometers, &c., by the firm we notice the L.W.V. wattmeter, for direct and phase power measurements, on balanced or unbalanced load, current ranges 750 and 100 amperes at 150, 300, 450 volts; the error from direct current to 0·60 period alternating will not exceed $\frac{1}{4}$ per cent. of the maker's own scale reading at power factors down to 0·3.

The electric instruments of Messrs. Everett, Edgcumbe and Co., of Hendon, N.W.9.—dwarf moving-coil meters, luxometer (recently improved), &c.—were mentioned last year. This year we also find the metrohm insulation testing set, new deflectional frequency meters for switchboards, &c., and a sample unit of the Everett-Edgcumbe Brazil carbon powder resistance, which has been put to use as earthing resistance for the neutral point on three-phase systems and as limiting resistance for over-pressure and lightening protective gear. The peculiar property of these powders is that their resistance decreases as the current flows, so that the current gradually increases until the fault is isolated by the opening of the circuit breaker. The shock to the system is thus minimised, whereas metallic resistance decrease as they grow hot and must therefore be made abnormally large. A unit is a trough of earthenware 15 in. by 10 in.

Of the exhibits of Messrs. Alfred Graham & Co., St. Andrew's Works, Crofton Park, S.E., we mention first the Graham Fire and Torpedo Control Instruments consist of step-by-step synchronous motors, indicating mechanisms, and transmitting switch gear within water-tight casing and with dial illumination, each fitting comprising from one to five combinations. The motor provides for 12 steps per armature revolution, by currents of from 10 volts to 25 volts, and correct operation is secured by means of a novel disposition of the armatures, the coils and the polar extensions and by the accurate workmanship of the devices. The six coils are connected in pairs in series, each pair having a resistance of 70 ohms; the current is, at 15 volts, 0·2 ampere when one circuit is completed, and less than 0.43 ampere upon energisation of the second pair. Our Figs. 3 to 13 will help to explain the arrangements. A cylindrical gun-metal casting is machined with extreme accuracy, as shown in Figs. 3 and 4; 12 polar extensions, $\frac{7}{16}$ in. in diameter are forced into the six holes bored at each end and are staggered (see Fig. 9, and Figs. 10 to 13); the armature iron core is extended at each end to correspond with the staggered poles of the field magnets; the journals of tool steel are ground $\frac{7}{32}$ in. diameter, and the armature (nearly $\frac{7}{8}$ in. in diameter) leaves an air gap of 0·003 in. between the face and the influencing cores. There is a bearing for the armature shaft at each end of the cylinder in the dust- and water-proof casing. The six field magnets have extended cores of increased width for attachment to the polar extensions. Figs. 5 to 7 explain the assembling of the parts. Four conductors are required between the transmitting switch and the unit; the connections with the receiving parts, and the relative disposition of the connected coils and their extensions are shown in Figs. 8 and 9; the magnetic circuits will be understood from the diagrams, Figs. 10 to 12. In Fig. 10 the upper and lower electro-magnets equally influence corresponding limbs of the armature, and the armature shaft is not under stress; while the upper and lower magnetic circuits are complete and parallel, a further secondary circuit (armature and both electro-magnets) is being formed. When the second pair is energised, the first pair remaining energised, the armature assumes a position midway between the poles of the influencing magnets. The magnetic circuits then comprise the upper magnet first energised, the upper armature limb, and the upper magnet secondly energised; and similarly the corresponding lower electro-magnets and the lower limb of the armature. Subsidiary magnetic circuits exist also, but the exact location of the armature is due to the rapid building-up of the series circuits, as indicated in Figs. 12 and 13. Though apparently complicated,

the design lends itself to mass production, as has been carried out for the Admiralty, and the step-by-step motors admit of rapid manipulation of the controlling switch. There is ample cooling area for the coils.

With the aid of these motors and further mechanisms up to 25 orders can be transmitted on revolving drums; range readings be taken from zero up to any maximum by steps of 25, 50, 100 yards; bearing elements can be indicated to complete arc of training or to any limit by steps of ½, ¼, or full degree, and deflection elements be followed from one maximum to another. The full reading from 0 to 29,975 yards by steps of 25 yards may, *e.g.*, be carried out in less than 20 seconds. The Graham switch-gear is one of the instruments designed for changing-over and completing low-pressure circuits with particular regard to naval ordnance and torpedo-control. The switch casing is cylindrical; the blades are attached to a carrier which revolves about its vertical axis, and the operating hand lever or hand wheel of the rotary spring carrier is secured to the cover by means of a clutch; only the cover screws have to be removed for opening up the sockets. The blades are arranged in pairs, and the terminal blocks are formed in one with the fixed blocks and slotted so as to receive the pairs of spring blades; ample bearing surface is thus obtained, and the switch is self-cleaning. In forms of gear involving slow action, the operating hand wheel is connected to the carrier by worm gearing, and the contacts and blades are arranged for completing groups of circuits in pre-determined order. In the larger types, up to 150 conductors enter the switch casing. We mention also the loud-speaking telephones, of which the firm has made a speciality since 1893, especially for the Navy. Specimens of various naval telephones, head-gear, receiver fittings, water-tight hooters and rattlers, and signal transmitters and fuses are also on view.

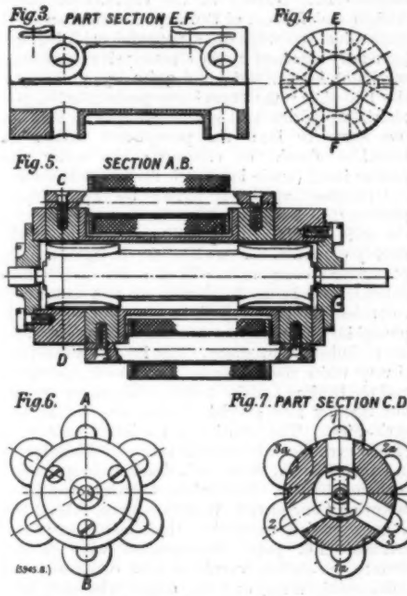
The auto-charger of Messrs. A. Graham and W. J. Rickett is designed for supplying low-tension current for telephones and, in particular, the loud-speaking telephone of Mr. Graham, from high-pressure continuous-current mains through secondary batteries. This can be effected by means of potentiometer resistance sets or by small rotary converters; but both these methods are wasteful. In the auto-charger a comparatively small current is taken from the mains through a resistance to the battery, this current assisting in supplying low-pressure current; that resistance and relays allow the battery to become fully charged, and the main supply circuit is then broken. The main relay (Fig. 14) is permanently connected across the low-pressure leads; as long as it operates, the battery is also joined to the windings of the control relay, and the one contact of the charging relay current from the battery then flows through the control relay and the "kicking" resistance in series to it. When the battery volts fall below a fixed value, the control relay will not operate, but the charging relay receives current from the mains and feeds the battery. When the volts rise above a fixed value, the control relay connects the middle junction of the main and charging relays to the negative pole and short-circuits the charging relay. While charging, the "kicking" resistance is in circuit with both the charging and control relays, and the voltage applied to the control relay is equal to the battery pressure minus the small potential across the terminals of the "kicking" resistance. As soon as the control relay short-circuits the battery, only the current from the charging relay will pass through the "kicking" resistance, the voltage across the resistance is automatically diminished and the potential across the relay is increased; thus the closing of the control-relay contacts is facilitated; similarly the breaking of the circuit is assisted, and "chattering" is prevented. The current consumption of the auto-charger is very small; a battery of 50 ampere-hour capacity, supplying current at 20 volts from a 110-volt main, absorbs about 60 watts when the battery is under charge, and less than 10 watts when not charging.

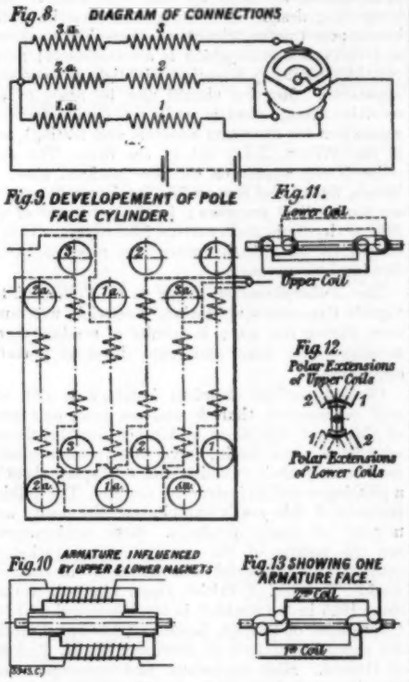
Street fire-alarm transmitters, push boxes, rain-proof bells and telephones are further exhibited by Messrs. Stuart and Moore, of Parkington-road, Acton, W.3.

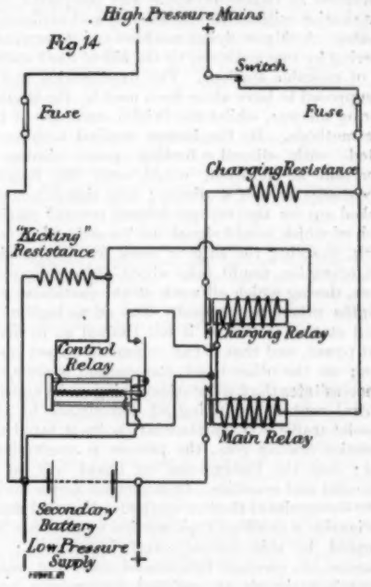
The Igranic Electric Company, Limited, of 147, Queen Victoria-street, E.C., whose coil-winding machinery we illustrated last year,* make this year a very impressive display of motor-starting lock-out switches, specially designed for roller-mills, which may have to start very slowly, or quickly, according to conditions, and of motor starters on continuous and phase circuits generally. Noteworthy are, further, the controllers for boring mills and lathes which enable the man to do his work in boring or turning car wheels of all sizes simply by pushing buttons; the electromagnets for workshop transport, the electromagnetic units of which are used singly or in combinations of 2, 3, 4, suitable for picking up scrap, long bars, heavy masses; and the battery-charging panels, fool proof in the hands of untrained men, which are also built up of units, the number of which is increased as the number of cars in use is increased. Some novelties in coil for track-signalling also deserve attention. We reserve illustrated descriptions of these novelties. Lifts and hoist controllers and automatic direct-current motor starters for pumps, lathes, printing machinery, &c., are further shown by the Watford Electric and Manufacturing Company, of Watford, Herts; the motor starters can be operated by pedal switches, push buttons, floats, and by contractor switches, in which care is taken that the bar always bears flat against the face of the resistance; the firm also makes the Kesnor machines, which issues aluminium-disc tickets for theatres.

The Edison-Swan Electric Company, of Ponders End, show pointolite and other lamps, valves for wireless telegraphy, platinum substitutes, and illustrate also the manufacture of molybdenum wire from the ore. Mr. Leoline Edwards, of Twickenham, has among his miscellaneous exhibits, the "Quidos" life-saving deck chair and other granulated cork appliances. Transformers are exhibited by the British Electric Transformer Company of Trixity House, 48, Oxford-street, together with various heating appliances; and condensers by the Dubillier Condenser Company of the Duron Works, Goldhawk-road, W.12. The condensers are of all types, also for artificial cables and for air or oil insulation, but the speciality of the firm lies in their superior mica condensers for up to 250,000 volts continuous or alternating circuit; all the mica is tested for use; the metal of the variable air condensers is brass or magnesium-zinc alloy, and the condenser cases are no longer made in wood, which may fail in tropical climates, but in ebonite or metal. In the electric heating line, the Dowsing Radiant Heat Company, of York-place, W.1 (soldering irons; the flatirons—for laundries—are pushed into contact-stands and do not require any cords), and Messrs. Arthur Lyon and Wrench, of 36, Victoria-street, S.W.1, deserve mention; the Lyon-Brotherhood domestic lighting plants for outputs from ½ kw. up to 4 kw., are built in complete units. Magnetos were plentiful last year; this year the Runbaken Magneto Company, of Cheetwood-lane, Manchester, has few rivals with its light-weight high-tension magnetos for motor-cars, cycles, &c., and stationary engines. A minor speciality, which might have been put in the engineering section, is shown by the Rawplug Company, of Lenthall-place, South Kensington; these plugs are made of twisted fibre and inserted into the holes drilled into plaster, brick, slate, stone, metal, &c., to receive screws, which are then less liable to crack the material; a 2-in. screw, fixed with rawplug in a stock brick, will, it is stated, withstand a direct pull of ½ ton.

The dictograph, of Dictographs Telephones, Ltd., of Denman-street, S.E.11, are loud-speaking telephones for house and office use, enabling a person to talk to, or to listen to, a person or several persons







* See ENGINEERING, September 26, 1918, page 247.

in an average-size room; neither the speaker, nor the listener need come up to the instrument, nor apply a receiver to his ears. A chief can thus give his instructions to the various employees in a room or in several rooms; when privacy is desired, an ear-piece is taken from a hook and used in the usual fashion, the other loud-speaking telephone being then cut out. The installation, which is worked by batteries or dry cells, consists of a master station and sub-station. When a sub-station is called up, a lamp flashes up; a sub-station calling up the master station would excite attention by a buzzer and shutter on an indicator; if the master should be busy, he can move a key and can continue his conversation undisturbed by any calls. When dictation is to be taken down, the dictator may move about and examine his papers, while the shorthand writer need not leave his desk. The "junior dictograph" comprises one master station and one or two sub-stations, the latter able to intercommunicate if desired. The motor dictograph is especially designed for service on motor cars.

The exhibits and demonstrations of Marconi's Wireless Telegraph Company have particular reference to radiotelegraphic and telephonic communication with ships and aircraft and to direction-finding. A ship or flying machine can determine its bearing by two methods, by the aid of fixed stations or of movable stations. The fixed-station method is supposed to have alone been used by the Germans during the war, whilst the British made use of both the methods. By the former method a ship—not fitted with direction-finding gear—wishing to ascertain its position, would send the letter V repeatedly for half a minute; this signal would be picked up by the various (three) coastal stations, each of which would signal the "reading" or angle back, enabling the ship to work out its position; the operation would take about three minutes or more, during which all work on the particular wave lengths would be stopped. The advantage of the fixed station is that it is not limited as to aerials and power, and that it can command expert operation; on the other hand, the method is slow, and it necessitates the fixed stations being under constant central control, excluding all disturbance by commercial traffic. When the craft is itself fitted with direction-finding gear, the process is much simplified; but the instruments on board will be less powerful and sensitive. Opinions are hence divided as to the merits of the two methods. For civil marine navigation a modified fixed-station method has been adopted in this country and in Canada; the beacons or wireless lighthouses send out easily-recognised signals at specified intervals, a wave-length of 450 m. being used in this country. The receiving aerial has the form of a wire loop, a rectangle or circle, which can pick up signals when the source lies in (or near) the plane of the loop, but will not respond to signals from other directions. When the loop aerial is a vertical frame fore or aft in the fuselage, the navigator will hear signals while he is flying towards the station or away from it, but his telephone will not respond to signals from other directions; by turning his machine he will hence be able to obtain information as to his position. On large machines the aerial may, as in land stations, be mounted so as to admit of rotation without altering the course of the machine. In these outfits two fixed looped coils cross one another at right angles; a third coil can be turned. The experimental arrangement at the Exhibition is the following:—The stand of the company has the form of a square hut; the two fixed coils cross one another diagonally on the roof, and the wires of each pass down one pair of opposite hut corners and are taken to a cylindrical box, about a foot in height, where the wires are continued in two small vertical rectangular coils, again at right angles to each other; the movable coil is wound longitudinally on the vertical axle of the cylinder which is turned by the hand wheel, the angle being read off on a dial. The aerials for small aircraft are simply twisted copper wires, up to 150 ft. long, loaded like log lines, and suspended from winding sheaves, which are bolted to the machine.

In the Marconi wireless telegraph set of ½ kw. the transmitter is of the synchronous spark type, giving a musical note of 600 periods; the transmitter wave may be adjusted to values ranging from 300 m. to 600 m., and the receiving gear be tuned to ranges from 250 m. up to 2,500 m. This is the cabinet type of apparatus; in the low-power set for aircraft, the two spark transmitters weigh 13 lb. and 25 lb. without gear, and have ranges of 30 miles and 60 miles respectively; with a sensitive valve receiver the whole set weighs 17½ lb. for 80 miles' range. For the short-range wireless telephone sets (range, 10 miles), which are not disturbed, it is claimed, by fogs or haze (interfering with optical and acoustical signals), valves are used. The receiver valves are of the ordinary grid and cylinder type; the grids of the transmitters resembling gas mantles formed of tungsten wire netting, surrounding the axial tungsten filament.

The high-tension apparatus and loaded telegraph transmitters of Mr. W. Hamilton Wilson, of Bank Broadway, Kingston Hill, Surrey, were described by Colonel Cusens before the Institution of Electrical Engineers in April last, in a paper on the Development of Army Wireless During the War. The instruments on view, 130-watt field sets, and ½-kw. transmitters, as well as the transformers and timing inductances, are lent by the War Office. The interesting design involves several novelties in the interrupter (motor-driven), the charging condenser and the spark coil (which is a transformer), and a very high efficiency is realised with light and compact apparatus. Mention should also be made of the sensitive thermo-electric appliances (conductors and generators for spectrum analysis and testing), and of the Wilson X-ray set of the firm. The only other X-ray apparatus we have noticed, those of Messrs. Schall and Son, of 75, New Cavendish-street, are for medical purposes; in the pantostat of the firm, a rhythmic main-current interrupter, a cam is turned by an electric motor and raises a needle dipping into mercury.

The Fullerphone of Major A. C. Fuller, of the Signals Experimental Station, Woolwich, was much used during the war; it admits of sending secret messages over long and used lines by portable apparatus.

Chemistry.—The chemical industry is not less well represented than it was last year, and some of the great dye firms and other establishments, who have come again, have taken commendable care to vary their exhibits, and to display them in a pleasing as well as instructive manner. The striking features of this year's exhibits are the purity and novelty of many products. Both achievements are the results of the energetic co-operation of colleges and industrial establishments in research work. The staff of British Dyes, Limited, worked since 1915 in "colonies" in the laboratories of the Universities of Oxford, Leeds and Liverpool, under the general direction of Professor W. H. Perkins, of Oxford. High explosives and aerodopes were likewise studied at Oxford; Mr. N. V. Sidgwick found in ethyl formate a substitute for acetone, and he succeeded in extracting phenol from the waste liquors of benzol sulphonation, in preparing toluene from Borneo petroleum, and in rendering aeroplane fabrics and even rubber fireproof. Scottish Dyes, Limited, formerly the Solway Dyes Company, of Grangemouth, have developed the "Sundour" colours, fast vat dyes for textiles. The results of the remarkable work by Professor Sir W. J. Pope and Dr. W. H. Mills, at Cambridge, on colour photography and on sensitisers can be examined on the stand of Messrs. Ilford; by the time of the Armistice 80 per cent. of the plates used were red-sensitive (panchromatic) and rapid, and the present search is for a sensitiser for astronomical photography which will respond to the infra-red while retaining its rapidity in the violet and ultra-violet. In working out the wholesale preparation of the mustard gas, shown by Professor Pope, both Cambridge and Oxford have a share. The Nobel research laboratories at Ardeer were among the first to take up the supply of pure chemicals, collections of which Messrs. Boots Pure Drug Stores, the British Drug Stores, of Graham-street, City-road, Messrs. Hopkins and Williams, of Cross-street, Hatton-garden, and other firms display in the Central Hall. The study of the stability and gelatinisation of nitric ester (nitrocellulose) powders at Ardeer and Waltham Abbey (Royal Gunpowder Factory) has led to the production of the Ardeer cordite, and it has been found possible by the addition of traces of certain substances to prepare explosive gelatine in the cold, instead of at 60 deg. C. or 70 deg. C. The research department of Woolwich Arsenal has, to judge by the exhibits, chiefly studied the nitro derivatives of toluene, dimethylaniline and cognate aromatic compounds. We can only allude to the great advance in therapeutical and physiological chemistry; the Wellcome Research Bureau, grown out of the Physiological and Chemical Research Laboratories, founded by Mr. H. S. Wellcome in 1894 and 1896, and other leading firms in this line are again represented at the Central Hall. The very useful research work done by the Board of Agriculture and Fisheries (exhibits of preserved fruit and vegetables, &c.), and of the Rothamsted Experimental Station, Harpenden, Herts (fertilisation, the fight against plant diseases and insect pests, seed-testing) should also be mentioned.

Our notice of miscellaneous chemical exhibits will have to be brief. Purity, of which the absence of colour frequently gives striking evidence, is the characteristic feature of the exhibits of Messrs. Alright and Wilson, of Oldbury, Birmingham. The ammonium persulphate, a powerful oxidising agent (generally obtained by the electrolysis of ammonium sulphate), is pure white and quite dry, probably for the first time; the phosphorus pentachloride, phosphoric anhydride and glacial phosphoric acid look like snow or ice; the phosphorus iodides and bromides should be coloured; the waxy phosphorus itself (made in electric furnaces) has turned red because exposed to light; the kibbled phosphorus (in beans), for flares on water, looks grey; the solid hydride $P_4 H_2$, yellow, we believe, when freshly prepared, has tarnished in the light, as many phosphorus compounds will do; the carbon tetrachloride and benzoyl chloride are still quite clear, colourless liquids. All these compounds, the zinc phosphide (for phosphor bronze) and tungsten, &c., are technically important. The lithium metal (more silvery white than sodium, but as easily tarnished) and the lithium hydride (obtained in snowy crystals, but turning into greyish lumps) are, so far, only curiosities. The British Alizarine Company, of Silvertown, the only manufacturers of this speciality in Great Britain, show the alizarine compounds in their full beauty. The British Cellulose and Manufacturing Company, 8, Waterloo-place, S.W.1, have a more varied exhibition than last year; their artificial silk, paper impregnated with cellulose acetate, insulating varnishes and tubes and non-inflammable films, and the doped wire and fabric netting (windows) are very interesting. The British Potash Company, of Oldbury, exhibits a product repeatedly mentioned in our columns, potash from blast-furnace dust. In the ammonium nitrate, caustic soda, synthetic phenol, &c., of Messrs. Brunner, Mond and Co., Northwich, purity and mode of preparation are the matters of interest. The finest, very large nitrate crystals were obtained by the oxidation of ammonia; the less conspicuous crystals from imported or home-made calcium nitrate and ammonium carbonate, or from Chile nitre and ammonium sulphate or bicarbonate. The salamac of the firm is a pure compressed ammonium chloride, the "Crex" is a new concentrated cleaner.

The samples of neutral ammonium sulphate of the Hydronyl Syndicate, 140 Leadenhall-street, E.C.2, demonstrate the technical importance of perfect neutrality and dryness. The ordinary ammonium sulphate of gas-works, utilised as fertiliser, is a somewhat greyish crystalline mass, more or less lumpy, which may contain ½ per cent. of free sulphuric acid and is hence hygroscopic, apt to rot the bags and storage bins of the sulphate, and to clog the farmer's drill in top dressing. By the Linder-Lessing neutralising process of the firm, a perfectly neutral granular dry sulphate is obtained which runs readily through the drill; this is demonstrated by putting the white grains, which contain 0·05 per cent. of moisture, in an hour-glass which the visitor is invited to turn. A number of gas-works and collieries have taken up this process. The Metro-sulphate of the South Metropolitan Gas Company, likewise a dry sulphate, guaranteed to

contain 25·5 per cent. of ammonia, 0·03 per cent. of moisture and to be free of acid, is prepared by a different process; the company demonstrates the dryness by blowing the grains up from a funnel in fountain fashion under a large glass bell. The other exhibits of the Hydronyl Syndicate are samples of hardened fats made by the hydrogenation of oils by Dr. R. Lessing's nickel-carbonyl process. In this very simple process the oil is blown with hydrogen impregnated with a very small percentage of the nickel catalyst in the form of carbonyl vapour. The nickel being in atomic condition at the moment of decomposition has a much greater surface than if it were used as solid metal; there is no danger of nickel poisoning, and the decomposed nickel is revolatilised by means of carbon monoxide and reconverted into the catalyst. The process which has been adopted by several firms, lends itself particularly to continuous working, and can deal, as the samples show, with olive oil, cottonseed, ground nut, linseed and whale oils; the fat obtained comes up to high-class lard in colour and hardness, and dark-brown whale oil loses all its fishy smell.

Of minor specialities we notice the insulating varnishes of Messrs. Thomas Howse, of Smethwick; the medco-soldering powders of the Middlesex Chemical Company, Langbourne Wharf, Millwall; and the sodium permanganate (not electrolytic, like the potassium salt), the green sodium manganate and brown barium manganate) (insoluble powder), all used as oxidising agents, as well as the alum and aluminium sulphate extracted from blast-furnace slag by the Stockton-on-Tees Chemical Works. The purification of clays by electrolytic methods, to which we recently referred in connection with Dr. Findlay's lectures,* is exemplified by Messrs. Catalpo, Limited, of Holborn Viaduct, who show applications of their "catalpo" (colloidal clay) in the dyeing, printing, enamel, leather industries and in catalytic processes, and by the Osmosis Company, of 36, Victoria-street, S.W. 1. The latter company treats the crude clay, or marl, stirred into water, in a trough in which a cylindrical electrode revolves; the fine clay is scraped off the cylinder, the coarse particles settle and are compressed into various products. Certain electrolytes are added to the water, and currents of several hundred volts applied; the company supplies machines turning out 14 tons of clay per week.

As regards non-corrosive iron for chemical plant we notice the tantiron of the Lennox Foundry Company, of Glenville Grove, New Cross, S.E. 8, (which has recently taken up electrically-heated subliming and drying vacuum ovens, and vacuum grinding and drying mills) and the porcelain enamel cast-iron vessels, up to 600 gallons in capacity, of Messrs. T. and C. Clark, of Wolverhampton. These well-known enamels resist nitric, sulphuric, hydrochloric and acetic acids—not alkalis nor alkali sulphates—and are utilised in sulphonating and nitrating pots, vacuums stills, tanks, conveyor pipes, elbows, &c., for laboratories as well as for plants. The "ceratherm" armoured centrifugal pumps of Messrs. Guthrie & Co., of Accrington, are made of acid-proof eathenware and said to be capable of working against a head of 150 ft., and of withstanding boiling nitric acid, hydrochloric, and sodium peroxide. We may mention also the vacuum drying machines for chemicals, preserves, &c., of Messrs. James Milne & Co., of Edinburgh, and their products.

Paper and textiles.—Chemical filter paper is now made in this country, also in the purest ashless grades, and Messrs. W. & R. Balston, of Maidstone, Kent (Whatman paper), as well as Messrs. J. Barsham Green & Son, of Maidstone, exhibit superior ashless and other filter papers in great variety; elastic gray filterings for oil are shown by Messrs. Evans Adlard & Co., of Winchcombe, Glos. Textiles are not strong. The Ministry of Munitions exhibits textile fabrics (wool, silk, cotton, linen) for their special objects; the University of Leeds illustrates the possibility of obtaining worsted yarns without combing the cotton. Cotton By-products Company, and Mr. E. de Segundo, of Dashwood House, New Broad-street, E.C., exhibit a working model of a cottonseed-defibrating machine which removes the residual cotton fibres left by the gin in a form suitable for the manufacture of paper, fibre, explosives, &c.; Messrs. J. Spicer & Sons, of Red Cross-street, Southwark, show paper food containers in addition to office file, &c.; and Messrs. Mellor Bromley & Co., of Leicester, have a Minotaur plain circular knitting machine working. Some of the firms engaged in engraving and illustrating display commendable taste in their artistic exhibits.

(To be continued.)

* See ENGINEERING, May 9, page 589.

LOCOMOTIVES FOR RAILWAYS IN CHINA.

On page 116 we give illustrations of two types of locomotives which have been recently made by the Baldwin Locomotive Works, Philadelphia, U.S.A., for service in China. In both cases the locomotives are of the Mikado type, and are of the 2-8-2 class. Fig. 1 is an illustration of the locomotives made for the South Manchuria Railway, Korea, of which twelve were supplied. They are built to the Baldwin standard designs, are capable of exerting a maximum tractive effort of 37,400 lb., and of operating on the railway where the grades range up to 2½ per cent.

The leading dimensions are given in column one of the Table given below, and it is interesting to add that wherever practicable the details are interchangeable with those on some ten-wheeled passenger locomotives supplied to the railway named by the same makers several years ago. The steam distribution is effected by piston valves (13-in. diameter) operated by Walschaert valve gear.

	Built for: South Manchuria Railway, Korea. Fig. 1.	Built for: Peking-Mukden Railway, China. Fig. 2.
Gauge	4 ft. 8½ in.	4 ft. 8½ in.
Cylinders	22 in. by 28 in.	21 in. by 28 in.
Valves, "piston" type	13 in. diam.	11 in. diam.
Boiler—		
Diameter	66 in.	68 in.
Plate thickness	⅛ in.	⅞ in.
Working pressure	185 lb.	180 lb.
Fuel	Soft coal.	Soft coal.
Staying	Radial.	Radial.
Fire box—		
Material	Steel.	Steel.
Plate thickness, sides	⅜ in.	⅜ in.
,, ,, back	⅜ in.	7/16 in.
,, ,, crown	⅜ in.	⅜ in.
,, ,, tube	½ in.	½ in.
Water space—		
Front	4 in.	4 in.
Sides	3½ in.	3½ in.
Back	3½ in.	3½ in.
Tubes—		
Material	Steel.	Steel.
Diameter	5½ in. & 2 in.	5½ in. & 2 in.
Number	5½ in. — 26 2 in. — 168	5½ in. — 24 2 in. — 172
Length	19 ft. 3 in.	18 ft.
Heating surface—		
Fire-box	163 sq. ft.	146 sq. ft.
Tubes	2,387 sq. ft.	2,219 sq. ft.
Fire-brick tubes	25 sq. ft.	—
Total	2,575 sq. ft.	2,365 sq. ft.
Superheater	612 sq. ft.	508 sq. ft.
Grate area	46·7 sq. ft.	41·4 sq. ft.
Driving wheels—		
Diameter, outside	57 in.	54 in.
,, centre	50 in.	48 in.
Journals, main	9 in. by 12 in.	9 in. by 10 in.
,, others	8½ in. by 12 in.	8½ in. by 10 in.
Engine truck wheels —		
Diameter, front	33 in.	37½ in.
Journals	5½ in. by 10 in.	5½ in. by 9 in.
Diameter, back	40 in.	43 in.
Journals	7½ in. by 12 in.	6 in. by 11 in.
Wheel base—		
Driving	15 ft.	15 ft.
Rigid	15 ft.	15 ft.
Total, engine	31 ft. 8 in.	31 ft. 4 in.
Total engine and tender	63 ft. ¾ in.	59 ft. 1½ in.
Weight, estimated—		
On drivers	154,000 lb.	142,000 lb.
,, truck, front	18,000 lb.	18,000 lb.
,, ,, back	26,000 lb.	28,000 lb.
Total, engine	198,000 lb.	188,000 lb.
Total, engine and tender	318,000 lb.	308,000 lb.
Tender—		
Wheels, number	8	8
,, diameter	34 in.	33 in.
Journals	5 in. by 9 in.	5½ in. by 10 in.
Tank capacity	6,000 U.S. gals.	6,000 U.S. gals.
Fuel capacity	14 tons.	8½ tons.

The locomotives of the type shown in Fig. 2, page 116, were constructed for the Peking Mukden Railway, China. This company placed an order for fourteen engines, and a further four engines to the same designs were supplied for the Lunghai-Pienlo Railway, also in China. These locomotives, although they generally follow the Baldwin standard designs, differ from them in that the frames and running gear follow European practice, and a further restriction was imposed, as it was a requirement that the overall dimensions should be such that they could be turned on a standard turntable having a diameter of 65 ft.

The frames of the locomotives shown in Fig. 2 are of steel plate 1¼ in. thick, strongly braced transversely by steel castings, plates and angles. The engines are capable of exerting a tractive effort of 35,000 lb. The leading dimensions of these locomotives will be found in column two of the table.

All the locomotives are fitted with superheaters, cast-steel piston heads of dished section with tail rods and cast-steel crossheads with cast-iron wearing shoes. They have roomy cabs of the American pattern, and are complete with all the usual fittings, boiler mounting and accessories.

The materials used in the construction of the locomotives comply with the requirements and specifications issued by the American Society for Testing Materials, whilst the whole of the threads on the screws and bolts are to the standards of the British Engineering Standards Committee. The chief particulars of the locomotives referred to are given in the table.

PERSONAL.—Major A. L. Young, late of the War Office and Directorate of Auxiliary Vessels, Admiralty, since being invalided out of the Army, has taken over the business of Bruntons, Limited, Sudbury, Suffolk, general engineers, brass and ironfounders and specialists in propellers and motor-boat fittings.

QUEBEC PROVINCIAL EXHIBITION.—The Imperial Trade correspondent at Quebec reports that the annual Quebec Provincial Exhibition will be held from August 8 to September 6, and he suggests that British manufacturers of road-making machinery, stoves, automobiles and parts, cutlery, &c., would find in this exhibition an opportunity for extending their trade in the Canadian market.

UNITED STATES EXPORTS.—According to *Boston Transcript*, a compilation by the National City Bank shows that the value of finished manufactures exported in the six months following the armistice aggregated 1,161,000,000 dols, or an average of 193,000,000 dols. per month. The corresponding 1913–14 average was but 61,000,000 dols. In the export of other groups of manufactures, classed as "manufactures for further use in manufacturing," there has also been an increase, but not as great. These averaged about 2,500,000 dols per day, compared with 1,000,000 dols. This growth in the exports of finished manufactures has been chiefly to South America, Asia, Oceania and Africa.

ELECTRIC REGENERATION ON SWISS MONOPHASE RAILWAYS.—The first experiment, on the recovery of the electric energy, which the braking or down-grade movement renders available, were made on the Lötschberg line of the Swiss Federal Railways, on June 27. The system tried was that of the Maschinenfabrik Oerlikon, and the success is described as complete. The tests were conducted with the locomotive which the Oerlikon Company, in conjunction with the Lokomotivfabrik Winterthur had built for the Gotthard Railway, and which has since May been in regular service on the Bern-Thun Railway. In the tests the engine was run at different speeds, up to 70 km. per hour, down hill, first empty, and then with a load of 310 tons, without making use of the mechanical brakes or of any brake resistances. It is said that the remarkably simple devices operated to complete satisfaction from the start, and the detailed account of the tests will hence be a matter of considerable interest.

QUALITY OF JAPANESE EXPORT GOODS.—Speaking recently at the London Chamber of Commerce, Mr. E. F. Crowe, C.M.G., counsellor to H.B.M. Embassy, Japan, said that Japanese Consuls in their reports and Japanese Ministers of State have often exhorted their compatriots to improve the quality of their exports. Furthermore, the Department of Agriculture and Commerce have inaugurated a system of inspection of exports, whereby certain classes of goods are carefully examined. Labels and stamps are affixed to goods which have passed the inspection, and none but such articles are allowed to be exported. This step became necessary, because it was found that very large quantities of inferior goods were being shipped abroad and were damaging the general reputation of Japanese exports. In theory the system is no doubt excellent. In practice it has probably stopped the shipment of absolute rubbish, but the number of inspectors is too small to permit of a careful examination of goods. Moreover, even were very careful examination to take place, it is not certain that the time thus expended might not frequently result in long delays super-imposed on already late deliveries, and would thus be as disadvantageous as the export of inferior goods. Mr. Crowe has been told by buyers of Japanese exports that what they complain about is not so much poor quality as unreliability. Provided the goods are equal to the sample, there is often a demand for an article of poor quality if it is cheap, but when articles are often worse and rarely better than the sample, and, on the whole, lacking in uniformity, it is hard to dispose of them. It will be difficult, however, if not impossible, to remedy this defect so long as Japanese articles are turned out as at present by cottage industry and by cheap labour working in very small factories. The only way to overcome it is by careful inspection and grading by the shipper of the goods, a shipper of repute who expects to do business with his customers for many years and not to make his profits off one transaction.

INDUSTRIAL NOTES.

A FURTHER improvement in the state of employment is shown by the information collected for the month of June, says *The Labour Gazette*. During the four weeks ended June 27, the number of unemployed persons whose Out-of-Work Donation policies remained lodged at Employment Exchanges decreased from 771,211 to 606,125, a drop of 21 per cent. Between the end of May and the end of June the percentage of Trade Union members who were reported as unemployed fell from 2·1 to 1·7. Reference to the detailed reports on the various industries reveals that in most cases there was either a slight improvement, or no appreciable change in the state of employment.

Increases in wages which came into operation in June affected 350,000 workpeople, and nearly 100,000 workpeople obtained reductions in hours of labour. At July 1 the general level of retail prices of food and other items entering into the cost of living was between 105 per cent. and 110 per cent. above the pre-war level, and was slightly higher than a month earlier, this being the first increase since the date of the armistice, when the general percentage increase was between 120 per cent. and 125 per cent. above the level of July, 1914.

The total number of persons in receipt of unemployment donation at June 27 was 606,125. The composition of this total was as follows: (*a*) Civilians—Men, 106,661; boys, 6,615; women, 113,462; girls, 6,544; (*b*) Demobilised: Men, 370,696; women, 2,147. An analysis of the policies lodged at June 27 revealed that 63,938 of the unemployed persons were in receipt of the reduced donation paid to civilians after the expiry of the first period of 13 weeks' unemployment.

The number of men on the live registers of the Employment Exchanges at July 4 was 516,263, or a decrease of 52,835 on June 6; and the number of women was 182,998, or a decrease of 73,040 on the total at June 6. The number of vacancies unfilled on July 4 was 44,904 for men and 55,289 for women, the corresponding figures for June 6 being 45,311 and 59,751.

Trade Unions with a net membership of 1,334,206, excluding those serving with the Forces, reported 1·7 per cent. of their members as unemployed at the end of June, as compared with 2·1 per cent. at the end of May and 0·7 per cent. a year ago.

The number of workpeople employed at coal mines included in the returns for the period ended June 21 was slightly greater than in the period ended May 24, and 20 per cent. greater than a year ago. Employment continued good at iron and shale mines, fairly good at lead and tin mines, and good generally at quarries.

In the pig-iron industry employment remained good. At iron and steel works it continued good on the whole, and was about the same as a month ago and a year ago. There was an improvement in the engineering trade in June, but there was still much variation in the state of employment in different centres. In the shipbuilding trade, employment remained good on the whole. In the tinplate trade employment continued good, and was much better than a year ago, an increase of 40 per cent. being recorded in the number of mills in operation. In other metal trades employment was fairly good on the whole.

There was a further improvement in the brick trade. Cement workers continued to be well employed, and worked a considerable amount of overtime. In the pottery and glass trades employment continued good. In the building trade employment improved and, taken as a whole, was fairly good. In the woodworking and furnishing trades employment was usually good or fairly good. In the paper and printing trades it showed a slight improvement; with bookbinders it remained slack. Dock and riverside labourers were fairly well employed; the supply of seamen was equal to, or in excess of, the demand. Fishermen were well employed on the whole, and the quantity of fish landed was nearly twice as great as in May.

The changes in rates of wages reported to the Department as having come into operation in June resulted in an increase of about 75,000*l.* in the weekly wages of nearly 350,000 workpeople. The principal changes affected women and girls employed in miscellaneous metal trades and in aircraft manufacture; and iron puddlers and iron and steel millmen in the Midlands. The changes in hours of labour during June affected nearly 100,000 workpeople, whose recognised working time was reduced by an average of about five hours a week.

According to *The Iron Trade Review*, Cleveland, Ohio, organised labour seems determined to abolish premium and bonus systems; its efforts to demand high wages without giving value received are inconsistent, and ignore the economic equation. The manufacturer of the present day faces serious problems which in the easy days of ten years ago were much less vital. He must pay high wages, enormous taxes, build modern plants and put down up-to-date machinery or be outdistanced.

A consistent premium or bonus system, whereby the honest worker is rewarded in direct proportion to his efforts, aids materially in helping the manufacturer to get value received from the wages he pays. Yet organised labour cannot or will not admit the practical justice of this system. Its stand seems to be that labour must be continually employed at all hazards, including the poor workman and the indifferent. The slacker and the incompetent, according to the edicts of organised labour, must be paid as much as the fair-minded worker who does his best.

If organised labour were half as sincere as it pretends to be, it could not advocate measures to compel manufacturers to pay the lazy and the incompetent the same wages as are earned by the honest toiler. Productive efficiency is and must remain the guiding star of America if prosperity for employer and employed is to be enjoyed and kept. If labour and capital would co-operate as partners in business, the United States could embark on an industrial expansion programme, the like of which the world has never known. On the other hand, if labour is so blind that it cannot see the employers' side of the question, we (the United States) are bound to be seriously handicapped, while more progressive nations reap rewards of reconstruction.

The American Federation of Labour, says *The Iron Age*, New York, adopted a resolution at its Atlantic City convention, declaring that a broad programme of scientific and technical research is of major importance to the national welfare, and should be fostered in every way by the Federal Government, and that the activities of the Government itself in such research should be adequately and generously supported in order that the work may be greatly strengthened and extended.

With regard to the advance of 6*s.* per ton in the pit-head price of coal referred to in our last issue, the Government proposed to postpone the application of this advance, provided the miners agreed not to strike for a period of three months. This offer on the part of the Government was rejected at the Miners' Conference held at Keswick on Thursday, the 17th inst., by a resolution which reads as follows:—

"This annual conference, having heard the report of the miners' Members of Parliament upon the discussion in the House on the Government's proposal to raise the price of coal by 6*s.* per ton, declare that the increase is not necessary, and should be avoided. It regards the problem as one of production only. It is of opinion that production can only be increased to a point which will make the industry self-supporting, without additional charges to the consumer, if the economies set forth in the first Sankey Report are effected and the recommendation of the majority of the Commissioners as to an immediate change of ownership and control in the mining industry be passed into law.

"It further informs the Government that it is prepared to co-operate with the Government to the fullest extent to put such economies into effect and the recommendations into law."

The 6*s.* advance came into force last Monday.

At the same conference another resolution was passed, dealing with the piece-rate difficulty. It states:—

"That this conference decides that the maximum figure to be accepted in any given district for the reduction of one hour per working shift is to be 14·3 per cent., with a proportionate increase for every fractional part of an hour reduction, provided that such increase in rates shall not mean an increase in actual wages. This conference instructs the Executive Committee to acquaint the Government with this decision, and to obtain an interview with the object of a settlement on the above basis. In the meantime, all districts are requested to continue working until instructed to the contrary."

Notwithstanding the request in this second resolution, the strike in the Yorkshire coalfields mentioned on page 80 *ante* has continued and has increased in intensity. Speaking on the matter last Saturday at Barnsley, Mr. Herbert Smith, President of the Yorkshire Miners' Association, said that his association had been dealing with the position of the Sankey award since June 16, and had not sought to depart from the award at single shift collieries, with the exception that they asked for a uniform six-hour day for Saturdays, where at present working conditions varied from 6¼ to 5½; they would still be giving 46¼ hours work per week. At double-shift collieries the surface men before the Sankey award were working 46¼ hours per week inclusive of meal times, and some less. All the association had done in this connection was to ask for a continuation of customs that had prevailed in the county. In regard to the 14·3 per cent. for piece rates, their application was for 16·66. After many meetings with the owners they arrived at 14·3 as a basis of settlement. If they had been met by the West Yorkshire owners in a spirit similar to that shown by the South Yorkshire owners there would not have been much left to settle on the 15th inst., the date on which the strike started. But with the Coal Controller's interference and the timidity of the coal owners in West Yorkshire they had arrived at the present position, and the men had taken this step in a constitutional manner.

On Saturday last, over 50,000 men in charge of pumping and other safety operations at the Yorkshire collieries went out on strike. Owing to the extreme gravity of the situation, the Government decided, on Sunday, to send to the collieries men from the Navy for working the pumps and the ventilating machinery. On Monday Sir R. S. Horne, the Minister of Labour, sent the following letter to Mr. F. Hodges, secretary of the Miners' Federation of Great Britain:—

"The Government directs your attention to the resolution of the Miners' Conference on Thursday, July 17, instructing the men connected with the mines to remain at work pending a meeting between the Government and the Miners' Executive regarding piece rates.

"In this connection the Government are anxious to know what action the Federation proposes to take regarding the calling out by the Yorkshire District Council of the pumpmen in the Yorkshire coalfield, owing to which many mines are at present being flooded.

"I need not point out to you the disastrous consequences of this action. It involves the ruin of the mines, many of them permanently, and will have the result of destroying the means of livelihood, not only of the miners themselves, but also of all those in the Yorkshire district who are dependent on the coal industry.

"In view of these grave consequences the Government felt compelled yesterday to send men from the Fleet to give aid in working the pumps, but these would be withdrawn as soon as the Federation can induce the regular workmen to return to duty.

"As this is a matter of great urgency, I am instructed to ask for an immediate reply."

At the time of going to press, no reply had been received by the Minister of Labour to his letter.

In the meantime several Yorkshire collieries are flooded, others are threatened with the same calamity, and the strike has extended to the collieries of neighbouring counties. Industrial establishments in Sheffield, Leeds, and other centres are gradually closing down through lack of coal.

Sir Eric Geddes has set up in Leeds a Department for Coal Mines Maintenance.

SWEDISH IRON ORES.—Professor Anderson, of Stockholm University, recently stated in the course of a lecture that Sweden was able both to export her ores and to melt them in the country for the manufacture of Swedish pig-iron, but she had to use discrimination in the matter. The Swedish iron-ore exports aggregated only 92,000 tons last April, as against 213,000 tons in April, 1918, and 259,000 tons in April, 1917. Pig-iron exports last April were 9,917 tons, and in April, 1918, 15,382 tons.

COAL PRICES IN THE FAR EAST.—People at home who are protesting so loudly at the high prices of all commodities, and at the present moment are particularly suffering from the addition to the price of coal, may not perhaps be aware that Britishers in some of our far-off Colonies are suffering even more from this cause. For example, we (*The London and China Telegraph*) hear that the present price of coal at Singapore is $45 a ton, or, say, 100*s.*—a figure which is calculated to give a shock to former residents in the Straits who lived there in pre-war days. In other parts of the East the rates are even higher, as, for instance, at Batavia, where bunkers are selling for 135*s.* a ton. Such prices as these must necessarily seriously affect commercial matters,

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BALL TEST FOR RAILS.—An account is given in *Engineering News Record*, New York, of the recent meeting of the American Society for Testing Materials. It states that precedents in American rail specification were broken by the Steel Committee, in abolishing the drop test for girder rails and high tee rails (for street-railway service), and replacing it by a ball impression test for hardness. The step was taken at the request of electric railway technical bodies, who desire a hard rail to resist wear, and do not consider brittleness a danger where rails are bedded in pavements. Extension of this change in method to railway rails is not thought likely. Further noteworthy features of the change are (1) that no upper limit of hardness is fixed, but merely a lower limit, and (2) that the Brinell test is not adopted, a larger ball and a much higher loading being specified. A ½-in. ball is to be placed on the head of the test rail and a load of 100,000 lb. applied for 15 seconds; the resulting impression should not be deeper than 3·6 mm. (0·141 in.) for class B, or 3·8 mm. (0·149 in.) for class A rails.

THE USE OF PULVERISED COAL.

*Use of Pulverised Coal, with Special Reference to its Application in Metallurgy.**

By L. C. HARVEY (London).

(*Continued from page* 67.)

SYSTEMS.

"HOLBECK" (BONNOT) SYSTEM.

The Bonnot dryer (Fig. 6) consists of but a single shell, and the hot gases from the furnace pass directly over the fuel to be dried. In America 30 or more installations are now in successful operation. At most of these plants the Bonnot pulverising mills and dryers are in use, but in some cases other standard types have been adopted. The arrangement may necessitate a tortuous line for the main supply pipe, but any increase in the number of curves or bends apparently only requires additional pressure on the air supply or the provision of booster mixing fans at certain points. The course followed by the coal after delivery at the track hopper and up to the pulverising mills is the same as in all other systems.

In the Bonnot pulverising mill (Fig. 7), the powdered coal is delivered into the cyclone separator, whence it passes into the storage bin, and is extracted therefrom in quantities controlled by the speed of the feed screw and mixed with air through the medium of a high velocity fan in the mill-house. Approximately, 40 per cent. to 50 per cent. of the air required for combustion is mixed with the coal dust in this manner, the mixture travelling through the supply pipes to the furnaces, under a pressure of some 10 oz. per square inch, and at a rate of 5,000 ft. per minute (roughly 1 mile per minute).

Any portion of this air and coal dust mixture not used in the furnaces is returned by the loop system to the cyclone separator wherein the coal dust is collected and the air with which it was mixed is discharged into the atmosphere. The extracted coal dust is returned to the storage bin for remixing in the mill-house fan. There must necessarily be times when only a few furnaces are in operation, yet the full supply of coal dust must be maintained as for maximum requirements. Power wastage at the mill-house mixing fans and for booster fans must be considerable under such circumstances.

In order to ensure that the proportion of coal dust and air in the supply pipe is constant, a special automatic regulator is used. The action of this regulator is dependent upon the rate of air supply to the fan. As the demand increases, so does the air-control cylinder valve open, and by means of a self-adjusting control device the speed of the coal dust feed screw is increased or reduced, and a greater or less quantity of coal dust is fed into the mixing fan.

In the author's opinion, further improvements have yet to be made in connection with this automatic control apparatus. The idea is very well conceived, but the actual apparatus is somewhat too complicated or too delicate to stand the test of rough mill-house use.

Burners.—The mixed air and coal dust is taken to the burners from the supply main by means of ordinary branch pipes in a similar manner to the supply of gas.

Branch control shutters or valves are placed close up against the supply main, in order to prevent the settlement of coal dust in the down pipes. The secondary air for combustion is delivered through a main air trunk to the burners in the usual manner.

As a rule, the Holbeck burners are fitted with end cover plates, and very often some of the ash slag deposited at the burner outlet is removed by raking it through the back ends of the burners. For high-temperature work the burners are water-cooled, which would appear to be a disadvantage, as it involves the addition of a complicated network of water pipes and a wastage of water.

Why water-cooling should be adopted with this system is not readily explainable, unless it is that on account of the more perfect mixing of the coal dust with the air supply before the fuel enters the furnace, combustion takes place closer to the burner orifice than with other systems. Coal dust and air are, however, often mixed some feet away from the orifice of the burner pipe in cases where water-cooling is not employed, and it would seem that the mixing of the coal dust and air would be almost the same in these instances as for the Holbeck system.

"QUIGLEY" SYSTEM.

Description of Mill-House Plant.—An outlay arrangement for a Quigley mill-house plant is shown in the "Report," so that it will only be of interest to reproduce a general view.

Fig. 8 represents such an installation in elevation, and the course of the coal from track hopper to blowing tank can be readily traced. The coal on delivery is put through the preliminary crusher; it is elevated to the magnetic separator, over which it passes to the crushed-coal bin. From this bin the coal is fed to the Ruggles-Coles dryer, which is fitted with an exhaust fan for removing the products of combustion, water vapour, and fine dust, the latter being deposited in the cyclone separator seen above the dryer. At the dryer discharge end the coal is elevated to the dry-coal bin, from which it is fed by gravity into the Raymond pulveriser.

The freed air in the cyclone separator is returned to the pulveriser. The positions of the motors for driving the plant, and that of the air compressor for coal-dust transportation to the furnaces, are indicated.

Air-Pressure Transportation of Coal Dust.—Fig. 9, page 126, shows the powdered-coal storage bin, the blowing tank, and the transport pipe line, in which semi-automatic switch valves are provided for diverting the coal dust into the supply bins at the furnaces.

The quantity of coal dust sent to any particular furnace bin is read off on the scale of the weighing platform on which the blowing tank is situated.

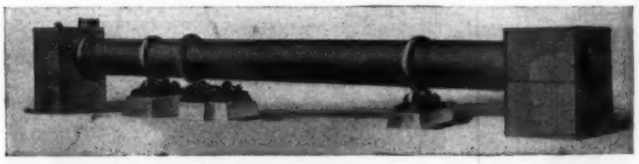


FIG. 6. THE BONNOT ROTARY DRYER.

FIG. 7. BONNOT PULVERISER AND AIR SEPARATOR.

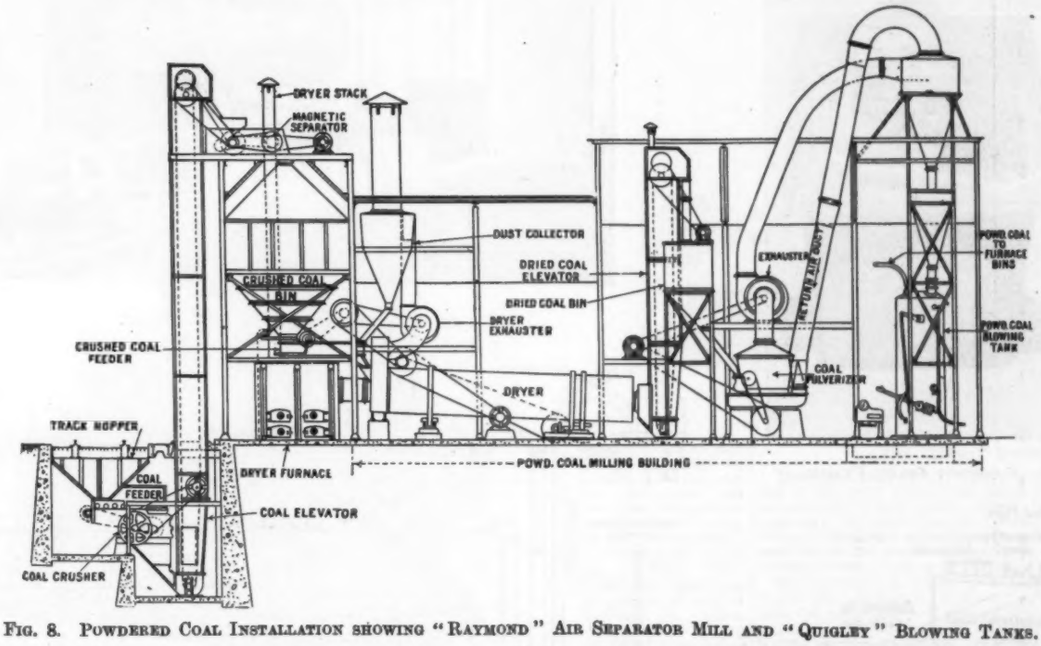


FIG. 8. POWDERED COAL INSTALLATION SHOWING "RAYMOND" AIR SEPARATOR MILL AND "QUIGLEY" BLOWING TANKS.

The cycle of operations is detailed on page 19 of the "Report."

It will be noticed that every furnace bin is fitted with a cyclone coal dust delivery separator. The air used in the propulsion of the fuel from the blowing tank at the mill house escapes through the vent pipe attached to the cyclone separator.

That this system has distinct advantages in connection with the delivery of coal dust through ordinary supply pipes, as for gas or water, is unquestionable. Coal dust can be readily conveyed into the bunker cylinders of a ship in dock, or special colliers can be used for coaling ships in harbour or at sea.

It has been suggested that a coaling barge, having air-tight bunkers for powdered coal, would be most suitable, and each bunker would be provided with one of the semi-automatic switch cylinders mentioned above.

Coal-Dust Feeders.—The universal practice is to make use of the single or double flight screw feeder. In most systems the worm is operated by a variable speed motor in order to control the quantity of coal dust fed into the air-blast at the burner. For the purpose of eliminating the variable speed motor, the Quigley constant-speed feeder shown in Fig. 10, page 126, has been used with success, and it is possible in this manner to run a number of feeders from line shafting.

THE "FULLER" SYSTEM.

This is undoubtedly the pioneer system for the use

* Paper read before the Iron and Steel Institute on Thursday, May 8, 1919.

of powdered coal. The chief feature of a Fuller installation is simplicity of lay-out from the raw coal track hopper to the furnaces. The coal and coal dust in the mills are of the screen separator type, the pulverised coal being delivered into the boot of a bucket elevator discharging into the screw conveyor transport line.

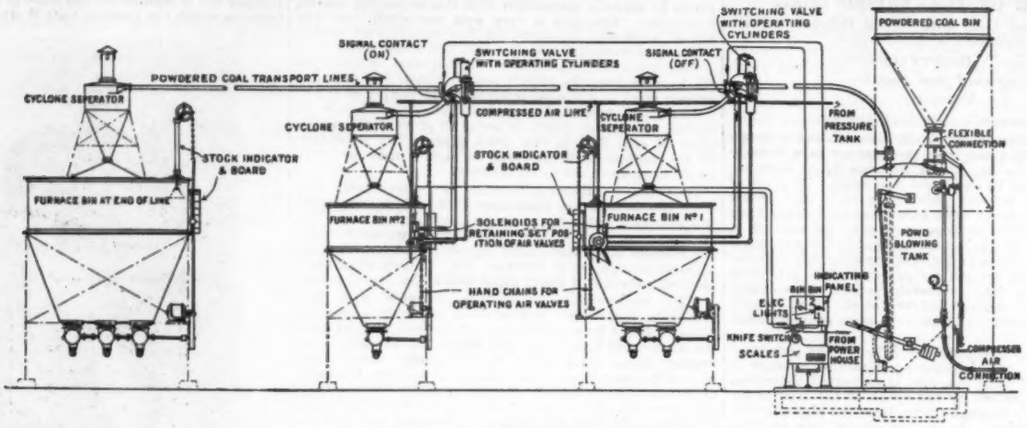


FIG. 9. "QUIGLEY" SEMI-AUTOMATIC BIN FILLING SYSTEM.

FIG. 10. CONSTANT SPEED FEEDER.

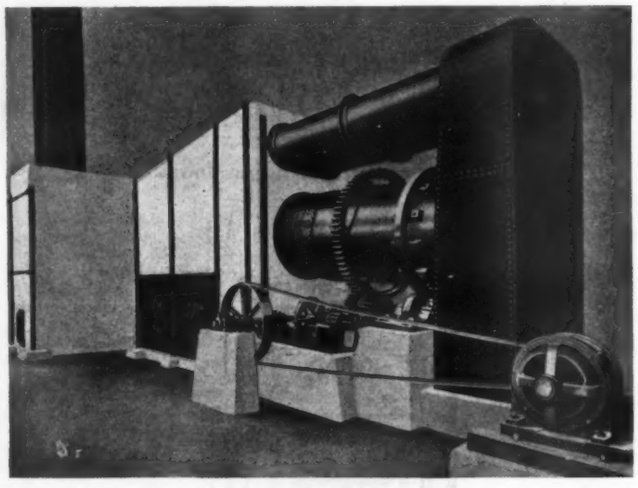


FIG. 11. FULLER ROTARY COAL DRYER.

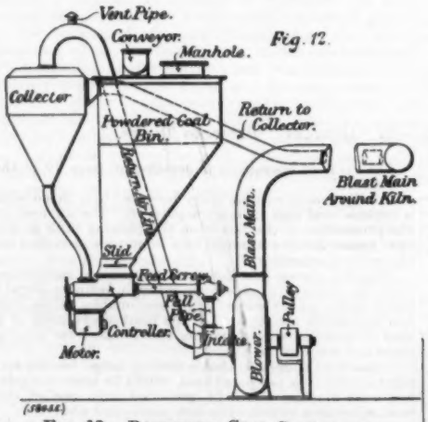


FIG. 12. POWDERED COAL SYSTEM FOR BRICK KILNS.

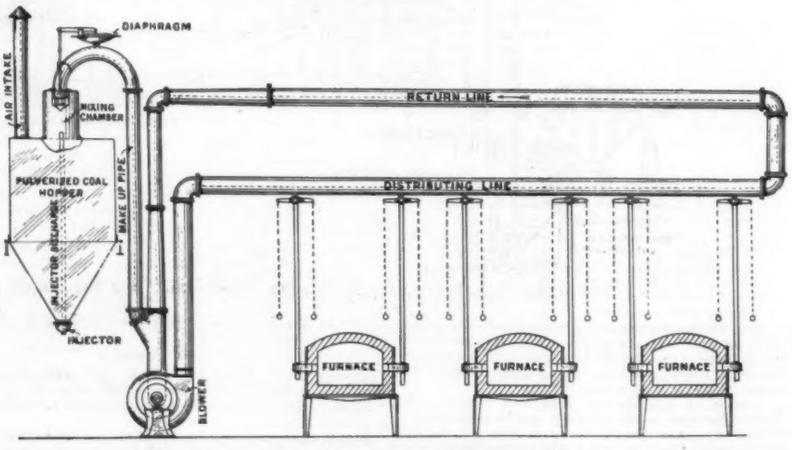


FIG. 13. "COVERT" SYSTEM.

mill-house are handled by means of bucket elevators and screw conveyors, and the latter means of transportation is generally employed to carry the coal dust to the points at which fuel supply is required. The standard Fuller mills can equally well be made with air-separator fans, but as a rule the makers prefer to supply their screen mills rather than fit the mills with coal dust exhaust fans for the following reasons; these can be taken as applying to air separator mills in general.

(a) For equal output of coal dust 25 per cent. to 50 per cent. additional power is necessary for air-separator mills.

(b) Suction fans for air separation must be run at high velocity, 1,000-1,250 r.p.m., depending on fineness required, quantity of coal per hour, position of fans in relation to cyclone separators, &c. At this speed fans having wheels of 42 in. diameter or so bear a tremendous strain. The wearing effect of coal dust on the fan blades is often excessive, and renewals of fan blades will be required every few months.

(c) The power required for this operation to remove 4 tons of coal dust per hour is some 35 h.p., whereas a bucket elevator used in conjunction with a screen separator mill requires but 5 h.p. for the same duty.

(d) In a measure, Fuller screen mills are provided with suction slow-speed fans integral with the grinding elements. The action of these fan blades is sufficient to collect the dust from the grinding zone and to force it through the screens. The power to operate these fan blades is but 1 per cent. of the power taken by the mill, whereas for air separation the power for the exhausting fan may be 35 per cent. or 40 per cent. of the mill power.

It is claimed that the Fuller mill has a larger grinding surface than any other mill of its kind, due to the circular movement of the pushers and balls which operate in a concave-shaped grinding ring. The effective pulverising surface is, therefore, greater than in mills fitted with vertical shafts to which rollers are attached, in which case effective grinding only takes place at the circumferential points of contact between the rollers and the bull ring.

The Fuller dryers differ from the Bonnot, Ruggles-Coles, and Cummer dryers in that the heating chamber surrounds a considerable portion of the drying cylinder. In this way the heating gases come in contact with the walls of the cylinder; they then pass through a duct to the end of the dryer, returning through the cylinder

This equipment forms a self-contained plant suitable for a small furnace shop. Such an arrangement can often be used to advantage in conjunction with the usual bin system for other parts of the works, and forms a supplementary system for use under special circumstances. The powdered coal is delivered to the fuel bunker by screw conveyor and the mixing operation effected through the medium of the rotary fan.

The author is indebted to Mr. Bergman for many of the comparative results between powdered-coal fired furnaces and those heated by other means, which are mentioned in this paper and the "Report."

"COVERT" SYSTEM.

Mr. Covert has aimed at supplying specially designed apparatus to suit each individual application, and to this end the continuous coal dust and air mixture system shown in Fig. 13 has been devised.

This is again unlike the pioneer "Holbeck" system in that the return of surplus mixture is taken direct to the mixing fan inlet, there being therefore, little waste power in dealing with this surplus fuel and air. Any deficiency is drawn from the mixing chamber at the top of the main fuel tank. Coal dust is injected into this mixing chamber by means of a small quantity of compressed air, and the actual supply of coal dust and air withdrawn is regulated by the diaphragm control shown at the top of the make-up pipe.

The special screw feeder supplied in connection with the Covert system is shown in Fig. 14. This arrangement of interconnected cross-feed screws ensures a regular feed and to a great extent prevents flushing.

Coal dust is conveyed by screw conveyor or by means of compressed air, and at one plant visited coal dust was transported by the latter method a distance of 1,500 ft. through 1,782 ft. of 3-in. pipe (allowing for bends and detours).

One or two of the more important points claimed for this continuous air and coal dust distributing system are:

(a) That the coal dust is not separated out after having once been mixed with air, and is, therefore, not subjected to an oxidising process more than once. This practically removes the difficulty experienced with other air and coal dust mixture systems as applied to low-temperature furnaces in which it is sometimes impossible to burn partially oxidised coal dust.

(b) In other systems the larger particles of coal dust, due to their momentum and inertia, pass the branch openings to furnaces and are returned to the main fuel bin; in consequence a collection or strata of coarse coal is often present in bins connected with such systems. In the Covert system all coal once taken from the bin is in constant circulation until burned, any coarse particles being ultimately split up in the mixing fan.

(c) The mixture is supplied at constant velocity, and is, therefore, at constant richness, no matter how many furnaces may be working at one time.

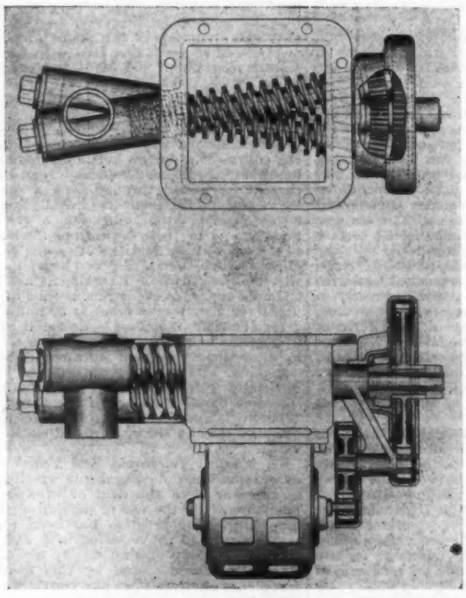


FIG. 14. "COVERT" SCREW FEEDERS.

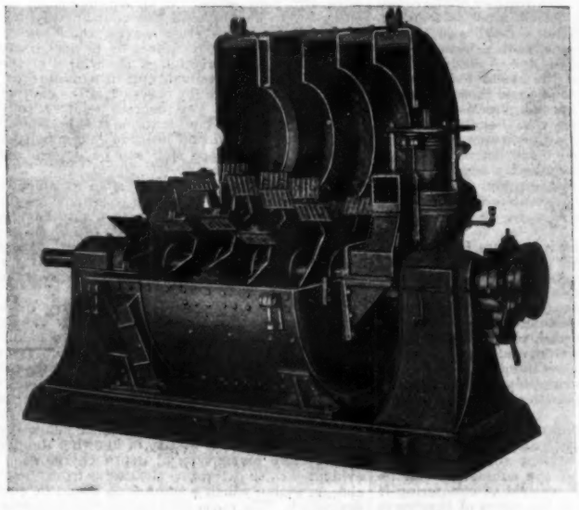


FIG. 15. "AERO" PULVERISER MILL.

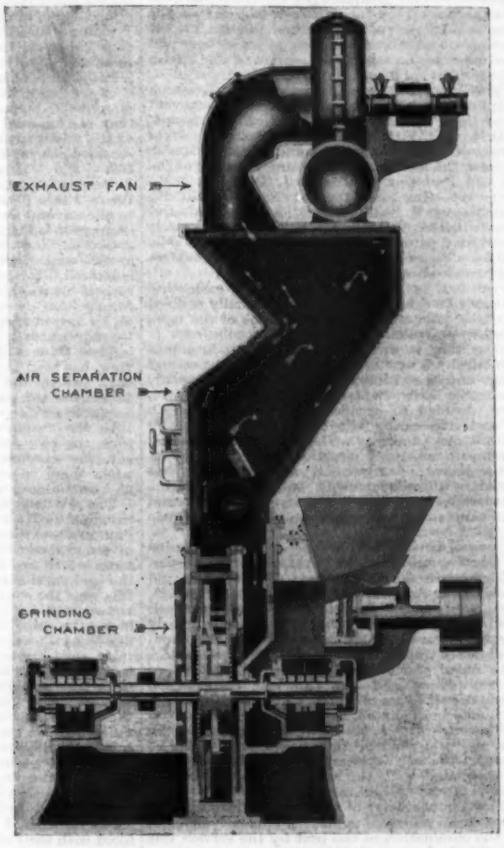


FIG. 16. "STROUD" AIR SEPARATION PULVERISER. (VIEW FROM FRONT END.)

in direct contact with the coal. This type of dryer is shown in Fig. 11, page 126.

The "Fuller" equipment for locomotives is referred to in the "Report" and later on in this paper.

THE "BERGMAN" SYSTEM.

Mr. L. H. Bergman advocates the bin system of fuel storage at the furnaces or boilers, and he uses standard mill-house equipment such as Ruggles-Coles dryers, Raymond Mills, but for certain special cases an air and coal dust mixture system is supplied.

A diagram of this system is shown in Fig. 12. It differs from the "Holbeck" in that the surplus mixture not used in furnaces is returned to a cyclone separator, but the coal dust extracted therein, instead of being returned to the main fuel bin, is returned to the coal feed-screw, the freed air and fine dust which may be still in suspension is withdrawn direct to the mixing fan inlet instead of being exhausted into the atmosphere.

THE "AERO" SYSTEM.

The Aero mill is a small compact pulveriser unit, and it has been extensively adopted in cases where a comprehensive mill plant cannot be entertained. As a means of pulverising fuel to a certain degree of fineness it has proved very satisfactory, but it will not produce coal dust at the degree of fineness required for efficiently heating certain types of metallurgical furnaces.

The pulveriser is shown open in Fig. 15. It is of the beater type, and no dryer is used as a rule. Coal is fed into the reciprocal feed chamber, coal and air entering together; the pulverisation and air-mixing takes place during the one operation. Rotary fan blades attached to the main shaft at the discharge end induce a current of air through the mill and remove the particles of coal.

It can only be said that this is more or less of a crude type of apparatus in comparison with the comprehensive plants described, but it fills a gap where small quantities of pulverised coal are required.

Apart from particular applications where this unit is preferable, it can be made use of to advantage when preliminary experiments are to be carried out in advance of making a decision as to whether a complete mill-house plant should be installed.

"STROUD" SYSTEM.

Another type of small self-contained pulveriser apparatus is shown in Fig. 16. This apparatus belongs to the disintegrator class of machines. Coal of $\frac{1}{4}$ in. to 2 in. cubes can be fed into the pulveriser, and the lumps are thrown against each other and against the rough-toothed lining plates by the rapidly revolving beaters. When pulverisation has taken place the dust is extracted by means of an exhausting fan, fineness depending upon the speed of the latter and the velocity of the air current through the grinding chamber. Coarse particles fall back into the grinding chamber. Like the "Aero"

this machine would be useful for supplying small quantities of pulverised coal and for making trials on furnaces prior to installing a complete mill-house plant.

(To be continued.)

SCIENCE AND ITS APPLICATION TO MARINE PROBLEMS.*

By Professor J. C. McLennan, O.B.E., F.R.S., Scientific Adviser to the Admiralty.

Introduction.—In the great struggle which has just been brought to its close the introduction and use of the submarine as an agent of unrestricted warfare by our former enemies, constituted a menace of paramount and vital importance to the safety and welfare of the British Commonwealth and of its allied nations.

As early as 1915, a Board of Inventions and Research was set up in the Admiralty under the presidency of Admiral of the Fleet the Lord Fisher of Kilverstone, G.C.B., O.M., G.C.V.O., LL.D., for the purpose of developing anti-submarine devices and systems capable of coping with the menace. This Board consisted of the President and Professor Sir Joseph J. Thomson, O.M., Pres.R.S.; the Hon. Sir Charles Parsons, K.C.B., F.R.S.; Sir George T. Beilby, F.R.S.; and Vice-Admiral Sir Richard Peirse, K.C.B., K.B.E., M.V.O.; and it was assisted by a panel of the ablest scientists available, as well as by a secretariat and series of sub-committees of leading naval officers and scientific experts.

In the autumn of 1917, after exhaustive researches had been carried out by this Board, it was finally realised by all that the submarine problem was one of the most difficult ever presented to science for solution. It became clear that it was necessary to introduce into service practically a new system of physical science and engineering, and the Admiralty, at the instance of the Right Hon. Sir Eric Geddes, G.B.E., K.C.B., M.P., First Lord, decided to broaden the field from which scientific and engineering talent could be drawn, and set up within the Admiralty a Department of Research and Experiment under the direction of Mr. Charles H. Merz. The Board of Invention and Research was incorporated in this department, and Anti-Submarine Committees were constituted in such important industrial and technical centres as the Lancashire and Clyde districts.

In the naval service, too, a special Anti-Submarine Division was organised under Captain W. W. Fisher, C.B., R.N., and in the Department of Torpedoes and Mines under Rear-Admiral the Hon. E. S. Fitzherbert, C.B., and later under Captain (now Rear-Admiral) F. L. Field, C.B., R.N., provision was made for greatly extending by research, experiment and trial the capabilities and use of improvements in mines and torpedoes as aids to naval warfare. Steps were also taken to promote the closest and most efficient co-operation between the departments of the naval service and those of the civilian scientific staff.

Extensions were also made in their organisations by our Allies, and as a result of this great effort it may be stated that by the late summer of 1918 it became clear to those associated with the movement, that the submarine problem was well in hand from a scientific point of view, that the character of the means of coping with the menace in an effective manner was clearly defined, and that the elimination of the pest by the service was only a matter of a few months' time.

At the time the Armistice was signed, only a few of the most powerful and effective devices developed were actually in service, but the results which were obtained by means of these for the short time they were in use were proportionately great. It is but right to say that the destruction of by far the great majority of the enemy submarines which were rendered innocuous was accomplished by the Naval Service by the use on an enormous scale of the ordinary methods available to it before the war began, or which were rendered available to the service in the early years of the war. Potentially, however, science by its advances has greatly extended the basis of service methods, and though much has yet to be done in the field of development of particular systems and devices it can be said, speaking conservatively, that the submarine in its present stage of development and in the method of its use hitherto adopted by our former enemies has been overcome as a menace to our national safety and well being.

For several reasons one in my position cannot give details of a number of the measures taken and means of destruction adopted in the anti-submarine campaign, but it is in the national interest to foster and stimulate co-operation by our people in the development of science and of its application to naval and other marine problems. In the following paper, therefore, a brief survey will be given of some of the most notable advances made in dealing with certain naval and marine problems presented to us on the naval side during the war.

Anti-Submarine Measures and Devices.

(a) *Listening Devices.*—As the power of the submarine in its attack is due to its invisibility, it is clear that in countering it methods must be employed which will reveal its presence and give definite information regarding its movements. Of all the physical disturbances emitted or produced by a moving submarine the pressure waves set up in water by vibrations having their source in the vessel are the ones which are propagated to, and are detectable at, the greatest distance. Efforts were therefore directed from the first to the development of listening devices. The investigations in this field were exceedingly ramified and were pressed with great vigour.

As a result great improvements were made in hydrophones. In the development of these devices microphones and magnetophones of exceedingly high sensitivity were realised, and after enormous labour, ways and means were devised for standardising their construction and their functioning. Hydrophones were constructed and put into service which were suitable for use in water of moderate depth, and other types were made which could be used in water of great depth. In one particular type of instrument modifications and attachments were introduced which enabled one to detect with it the direction of bearing of a source of sound with a fair degree of accuracy.

But probably the method of determining the direction of a source of sound waves in water which has proved to be the best is founded on the fact that the sound wave is in the same phase at all points of its wavefront. Thus, if there were two hydrophones, in themselves non-directional, placed in the path of the incoming sound, they can be used for finding the direction of the origin of the sound if the phase difference between the sounds received can be detected. There are two ways of doing this: the "binaural" method and the "sum and difference" method. The binaural method depends on the fact that if the sound from one receiver is conveyed to one ear and that from the second to the other ear, the impression is formed that the sound comes from a certain direction, and this direction, as interpreted by the sensations experienced, changes as the phase difference is altered. It can be brought to a certain position with respect to the listener (say, to the position directly in front) either by rotating the two receivers about an axis, or by introducing an artificial delay in some form of "compensator." This binaural method, which has great interest from a psychological and physiological point of view, has been the subject of much work on the part of both British and American scientists, and in the anti-submarine campaign it was found to be of very considerable service.

In the "sum and difference" method the impulses from the two receivers are united before reaching the ear, the combined effect observed being a maximum when there is no phase difference between the waves and a minimum when the phases are in opposition.

The French Navy has developed a hydrophone or listening device known as the Walser gear, which it has found very efficient. In this device two sets of a number of sound-receiving plates or studs are mounted on two areas which are convex to the sea, one on each side of the keel, on the underside of the hunting ship's hull. By this gear the sound impulses which they receive are not transmitted by tubes, but are given freely to the air inside the ship. These sound impulses are concentrated in a focus whose position in space depends on the direction from which the sound comes. The position of the sound focus is determined by means of a funnel or trumpet, from the contracted end of which a flexible tube leads to the listener's ear. The great advantage possessed by the Walser gear is that it enables one to distinguish by differences in the positions of the sound foci between sounds coming from a distant source and those generated in the water which have no specific directional feature characterising them. The gear can therefore be used by chasing ships when moving with fair speeds.

With most hydrophones and many listening devices, ship's noises and water noises generally seriously interfered with their effective use, and in practice the chasing ship is compelled to stop at intervals and listen when not under way. This means that in many cases the quarry is lost.

This defect was overcome in a measure by towing a directional hydrophone encased in an artificial "fish" behind a chasing ship. By adopting stream-line formation for the towed body and suitably supporting the hydrophone, water noises are fairly well eliminated. Moreover, as the "fish" can be towed at a considerable distance behind the chasing vessel, many of the sounds emitted by the latter do not reach it, and others which do arrive are received with weakened intensity.

It is needless to say that the development of sensitive listening devices received a great impetus by the use of thermionic amplifying valves.

Although an enormous expenditure has been made in time and effort to perfect the hydrophone and other listening devices, it is realised that such instruments possess an inherent defect. If the submarine can be made noiseless in motion, this method of countering it becomes ineffective. Even now the range of hearing is not more than 100 yards in the case of modern submarines moving at 2 knots or 3 knots.

(b) *Echo Methods.*—Owing to the fact that it was found possible under certain conditions to render the propulsion of submarines practically silent, it became necessary to look in other directions for fundamental methods of detecting them. A system of detection which is full of promise involves the use of a beam of sound waves sent out by a chasing ship in a manner analogous to the use of a searchlight. With such beams of sound waves it is possible to sweep the seas, and when an object of sound such as a submarine happens to come within the beam, the sound waves are reflected and echo effects are obtainable. The character of the beam is, of course, determined in large measure by the frequency of the waves constituting it. The method has been employed with great success, and promises to be a very helpful agent. It can be used by chasing ships travelling at all speeds, and when applied with certain restrictions and definite characteristics it enables one to pick up and close on a submarine situated more than a mile away. The method, it is obvious, is applicable to the locating of minefields and other obstacles to navigation as well as to submarine chasing.

(c) *Magnetic and Electro-Magnetic Detection.*—Magnetic detectors usually require the movable system to be poised or pivoted. They can therefore be used as yet with only a moderate degree of satisfaction in towed bodies or in vessels subjected to violent mechanical disturbances. The range at which magnetic effects can be detected is moreover comparatively short. As a result of these defects the use of magnetic detection is somewhat circumscribed. Such instruments can, however, be used under certain conditions, and in particular sea areas with great effect. In the war very considerable results were actually obtained by their use.

The range at which electro-magnetic detection can be applied is greater than is possible with magnetic detection, but the method is, however, essentially a short-range one, and in many of the forms in which it has been worked out it cannot be used with success at distances greater than about 300 yards or in depths greater than about 100 fathoms.

(d) *Leader Gear.*—An important application of an electro-magnetic effect which was developed during the war is found in what is known as Leader gear. This gear consists of a cable laid on the bottom of the sea along the course of a narrow tortuous channel leading into a harbour or through a minefield. If an alternating electric current be passed through such a cable it is possible by means of delicate devices installed on a ship to obtain either aural or visual indications of the presence of such a cable, and by these indications the ship can be guided in safety in fog or darkness at speeds as high as 20 knots almost with as much precision as a tram-car by a trolley wire over a railway. Experiment has shown that it is a simple matter to apply this method in water of suitable depth for distances as great as 50 miles or longer.

(e) *Invisible Signalling.*—Research has shown that it is possible under certain conditions to utilise polarised light or ultraviolet and infra-red radiations for secret signalling. With the last-mentioned type of radiation especially valuable results are obtainable over considerable distances, even in the presence of light fogs. Where it is not advisable to use wireless communication between chasing ships, infra-red signalling is of special value.

(f) *Wireless Telegraphy and Telephony.*—One of the most remarkable developments which have taken place in the war is in the field of wireless telegraphy and telephony. By the use of oscillating thermionic valves especially great progress has been made. It is now possible to hold conversation with ease between a land station or a ship and an airship or seaplane over considerable distances, and by this means observers on aeroplanes or aircraft can also converse with one another. With high-power installations it has been demonstrated that wireless telephonic communication can be maintained on the sea over hundreds of miles.

On the directional side of "wireless" great advances have also been made. If an aeroplane, an airship, or surface ship should send out continuously for a short interval a series of ether waves, these waves can be picked up over long distances by devices installed in a land station, the direction of the source of these ether waves can be ascertained, and in a minute or two the land station can give the observer of the emitting source his bearing within two degrees relative to the land station. With two land stations it is possible to obtain cross bearings, and the latitude and longitude of the sending air or surface ship can be determined with a high degree of accuracy.

With directional devices installed on ships it will be possible for two ships whose positions are known to communicate its true position to a ship enveloped in a fog and situated several hundreds of miles away. It is obvious, therefore, from the few illustrations which have been given that directional wireless will find a wide field of usefulness in the future in connection with the subject of navigation.

(g) *Explosion Pressures.*—In the early days of the anti-submarine campaign, a method of destroying submarines whose approximate location was known, was by the employment of depth charges. To use this means it was necessary first of all to know the neighbourhood in which the submarine was located, and then the chasing ship would rush to the spot and drop or throw to some distance charges of explosive which detonated when they reached a definite distance below the surface of the water. The necessity of knowing the destructive zone of any given type of depth charge soon became evident, *i.e.*, to dctermine the radius from the exploding charge, within which a submarine would be successfully destroyed. The same information was important in the laying out and use of minefields. Investigations were undertaken to determine what pressures were generated by charges of different sizes and types at various distances from the place of detonation. The nature of the pressure wave was particularly important, for upon it depends the "killing power" of the charge. The laws which govern the alteration in form and power of waves generated by these explosions had to be determined in order to employ depth charges and mines in the most effectual and economical manner. The accurate determination of the velocity of propagation of the explosive waves generated was also of importance in distributing the charges, for if waves from two different sources arrive at the object in different phases, the effective crushing power may be considerably altered. When we know what the effect of different charges at various distances is—what type of pressure wave, whether a sudden intense blow lasting a few ten-thousandths of a second, or a sustained pressure during some thousandths of a second, or a series of less intense shocks, has the greater effect in destroying the submarine when under water—then we shall know how best to lay out our minefields, and what size and type of charges are the best and most economical to utilise under the various situations which may arise.

* Paper read before the North-East Coast Institution of Engineers and Shipbuilders, at Newcastle-upon-Tyne, July 10, 1919.

A most elaborate investigation of the characteristics of explosion pressure waves has been carried out for the Admiralty by Mr. H. W. Hilliar. By this method the pressure is allowed to act on one end of a steel piston, and measurements are made of the velocity of the piston as it passes a series of points at known distances from its starting point. From these measurements it is only a mathematical operation to extract the acceleration of the piston at different times from the moment when it began to move; in other words, the time history of the pressure acting on the piston. It is not actually feasible to measure the velocity of a single piston at different stages of its travel, but you get the same information if you let the pressure act on a series of pistons and measure their velocity after they have travelled different distances. The velocity is found from the extent of crushing of a copper plug which the piston strikes when it comes to the end of its travel.

As an illustration of results obtained by the method it may be stated that with the measuring gauges at a distance of 50 ft. from a 300-lb. detonating charge of amatol placed about 50 ft. below the surface, the corresponding time-pressure curve showed that the maximum pressure, 0·80 ton per square inch, was reached almost instantaneously; that the pressure fell to one-quarter of its maximum value in 1/1,000 of a second, and practically faded away after 5/1,000 of a second. In the course of the investigation it was shown that the pressure waves are reflected from the water surface as waves of tension. The effect at any given point in the neighbourhood of the explosion is therefore due to the superposition of a direct pressure wave from the charge and a reflected tension wave from the surface: both travel with the velocity of sound (4,900 ft. per second) and the tension wave follows the pressure wave after an interval determined simply by the difference in the length of the direct and reflected paths from the charge to the point in question.

It has been found that the pressure from a large charge is more intense and more sustained than that from a small one, the two being connected by the following rule. If one charge has twice the linear dimensions of another (eight times the weight) the maximum pressure at a given distance from the larger charge will be the same as at half the distance from the small charge and will be twice as sustained, *i.e.*, will take twice as long in falling to any given fraction of the maximum.

When explosions of gunpowder, for example, were investigated, it was found that the pressure rose much more gradually than when charges of amatol or T.N.T. were used. With this explosive very low maximum pressures were obtained and the corresponding pressure waves were considerably prolonged.

Another method of investigating such pressures, which was suggested by Sir J. J. Thomson and applied by Mr. D. A. Keys, consists in the employment of the phenomenon long known to scientists, namely, that certain crystals become charged with electricity when subjected to pressure. The amount of the charge produced is proportional to the pressure applied to the crystals, so by having a suitable arrangement for measuring this charge and its variation with time, a complete record of the variation of pressure with time is obtained by placing the crystal detector at any given distance from the exploding charge. Since the duration of the wave in passing over the crystal or engulfing a submarine is only a few thousands of a second and the pressure generated may be of the order of half a ton or more per square inch, one can readily imagine the difficult nature of the problem in hand. But by making use of the inertia of a beam of cathode ray particles and employing the fact that they carry negative charges and are deflected by electrostatic and magnetic fields, it has been possible to obtain records of the variation of such pressures with the time. The electrons affect a photographic plate, *i.e.*, they leave an impression on the plate where they strike it. This additional fact has made it possible to determine the change in pressure of the wave from the instant the charge is fired and at as small intervals as we please afterwards. Changes which take place in 1/100,000 of a second have been recorded by this means. Already the method has revealed a number of facts about the nature of the pressure wave produced by exploding charges and the importance of such results in the laying out of minefields and the employment of depth charges can hardly be over-estimated.

(h) *Sound Ranging.*—In the course of our investigations of the characteristics of pressure waves generated by the explosion of charges in the sea, it was found that when a hydrophone was used to pick up the waves a good record could be obtained by the explosion of a number 9 detonator at least 2 miles away. The explosions due to charges of 2 lb. of T.N.T. have been recorded at 14 miles, and might have been recorded at far greater distances judging from the strength of the signals received. The explosions of 300 lb. depth charges have been recorded up to 200 miles, and it is probable that with charges of moderate amount explosions occurring as far away as 500 miles can be readily recorded. Based on these results a system of sound ranging under water was developed. Four hydrophones were laid out 5 miles apart along a base line in deep water a mile or two from the shore, and in addition two pilot hydrophones were placed along a line at right angle to the base line, the one 5 miles out and the other at twice that distance. Cables were laid from the hydrophones to a recording instrument situated in a shore station. Four of these stations were installed at different places along the east coast of the British Isles, and other stations are now in progress of installation. With such sound-ranging systems the shock of distant explosions occurring under water affect the various hydrophones in turn, and as time intervals can be read to two or three thousandths of a second with the apparatus now in use, it is possible to measure with accuracy the time intervals between the times of arrival of a sound wave at the different hydrophones. With the measurements of these time intervals it is a simple matter to deduce the position of the point at which the explosion setting up the wave is located. Up to 50 miles the location of an explosion under water can be determined to within a few hundred yards by a single station, but for accuracy the co-operation of two stations would be necessary to locate explosions at greater distances. Within operable ranges a ship can be given its position by sound ranging more accurately than by directional wireless or by any other known method. Explosions of mines or torpedoes at any point in the North Sea can easily be located by stations situated in Great Britain. In the war, during the bombardment of the Belgian coast it was a common thing for a monitor to proceed in a fog to a position some miles from the coast and by dropping depth charges have its position accurately determined from stations on the coast of England. So accurately was this done that it was found when the monitor's guns were trained in selected directions objectives several miles inland could be hit with regularity and with a minimum expenditure of ammunition.

(i) *Helium.*—Shortly after the commencement of the war it became evident that if helium were available in sufficient quantities to replace hydrogen in naval and military airships, the loss in life and equipment arising from the use of hydrogen would be enormously lessened. Helium is most suitable as a filling for airship envelopes in that it is non-inflammable and non-explosive, and, if desired, the engines may be placed within the envelope. By its use it is possible to secure additional buoyancy by heating the gas (electrically or otherwise), and this fact might possibly lead to considerable modifications in the technique of airship manœuvres and navigation. The loss of gas from diffusion through its envelope is less with helium than with hydrogen, but on the other hand the lifting power of helium is about 10 per cent. less than that of hydrogen.

Proposals had been frequently put forward by scientists in the British Empire and in enemy countries regarding the development of supplies of helium for airship purposes, but the first attempt to give practical effect to these proposals was initiated by Sir Richard Threlfall, who received strong support from the Admiralty through the Board of Invention and Research.

It was known that supplies of natural gas containing helium, in varying amounts, existed in America, and it became evident from the preliminary investigations made by Sir Richard Threlfall and from calculations submitted by him as to the cost of production, transportation, &c., that there was substantial ground for believing that helium could be obtained in large quantities at a cost which would not be prohibitive.

The writer was invited by the Board of Invention and Research in 1915 to determine the helium content of the supplies of natural gas within the Empire, to carry out a series of experiments on a semi-commercial scale with the helium supplies available, and also to work out all technical details in connection with the large-scale production of helium and the large-scale purification of such supplies as might be delivered, and become contaminated with air in service.

In the course of these investigations which were carried out, with the co-operation of L'Air Liquide Company, it was found that large supplies of helium were available in Canada, which could be produced at a cost of about 1*s.* per cubic foot.

In the spring of 1917, when the United States of America had decided to enter the war on the side of the Allies, and after the investigations referred to above were well under way, proposals were made to the Navy and Air Board and to the National Research Council of the United States of America to co-operate by developing the supplies of helium available in the United States. The authorities cited agreed to co-operate with vigour in supporting these proposals, and large orders were at once placed by them with the Air Reduction Company and the Linde Company for plant, equipment, cylinders, &c. The Bureau of Mines also co-operated by taking steps to develop a new type of rectifying and purifying machine. By July, 1918, the production of helium in moderate quantities was accomplished, and from that time forward the possibility of securing large supplies of helium was assured.

Concurrently all practical details of the construction of helium-borne airships and of the navigation of this type of craft were developed by the Airship Production Section of the Navy. At the same time, under the direction of the writer, plans were prepared and steps were taken to erect and equip a station for purifying the helium which might become contaminated in service.

Experimental investigations were also initiated with the object of developing all possible technical and scientific uses of helium. In particular, balance, spectroscopic and electrical methods of testing the purity of the gas were worked out, studies on the permeability of balloon fabrics to hydrogen and helium were commenced, and experiments were begun to exploit the use of helium in gas-filled incandescent lamps; gas-filled arc lamps, and in thermionic amplifying valves. The equipment provided for the purification of contaminated helium in large quantities supplied the major portion of the apparatus required to liquefy helium, and arrangements were therefore made to produce this gas in a liquid form for the purpose of carrying out low-temperature researches.

The advances actually made at the time the armistice was signed warrants the opinion that by the present time, had the work projected been completed, supplies of helium at the rate of 2,000,000 cub. ft. a month would have been produced within the Empire and the United States at a low cost, helium-filled aircraft would have been in service, and great progress would have been made in exploiting the technical and scientific uses of this gas.

Before the war a proposal to utilise helium as a filling for airships would have been viewed, even by most scientists, as impossible, but thanks to the enterprise, enthusiasm and initiative of the Navy, backed by imagination, a suggestion—at one time considered to be chimerical—has to-day become a realisation.

Defensive Measures.

From time to time publicity has been given to the steps taken by the British Navy in co-operation with the Navy of the United States of America to close to the passage of submarines such sea areas as the northern portion of the North Sea and the Straits of Dover.

At the time of the signing of the armistice, this stupendous task was well advanced. The material used consisted largely of ordinary contact mines, which were used in vast numbers and at the expenditure of enormous labour and capital.

It can be stated now, however, that concurrently with the installation of this system of defence, other systems of dealing with these and similar areas were worked out, which involved the use of more subtle mechanisms in quantities which were vastly smaller in amount.

To-day it is scientifically possible and practicable with a comparatively small amount of material to close effectively to the passage of submarines by either automatic mechanisms or by controlled ones such sea areas as the Bristol Channel, the water stretch between the Mull of Cantyre and the north coast of Ireland, the Straits of Dover, the sea area between Belgium and Denmark, the Cattegat and Skager Rack, and the greater portion of the North Sea between the Orkneys and Norway.

This will serve to show, in a measure, the part science has been able to play during the war. Had the knowledge we now possess been available at the opening of the war, we should have been spared much inconvenience, suffering and anxiety, for the submarine menace, at one time threatening and uncomfortably dangerous, would never have been able to materialise.

Applications of Science under Peace Conditions.

Under peace conditions many important technical systems and devices brought forward during the war will find immediate application as aids to navigation.

By means of directional wireless systems, ships or aircraft in the English Channel, the North Sea, or in the eastern and western portions of the North Atlantic, can be given their positions when prevented from getting it by the existence of fogs or unfavourable weather. By means of sound ranging it is possible to fix the positions of light vessels, buoys which indicate channels and obstructions, such as sunken ships. Ships steaming in fog up the Channel or approaching the shores of Nova Scotia, Newfoundland or Labrador, can be given their positions with accuracy for ranges up to as much as 500 miles. Seaplanes and aircraft in distress in the neighbourhood of the British Isles or near the coasts of America can call for help and be located when wireless gear becomes inoperable by simply dropping depth charges.

In hydrographic work generally sound ranging will be of the greatest service for surveys can be made and investigations of sea beds carried out in fogs as well as in fair weather without the delays which have been experienced in the past. The positions of the localities being investigated can always be determined in a few minutes when once a sound-ranging station has been established on some shore within reach.

By Leader gear laid in such areas as the River St. Lawrence, the entrance to the Thames or to Halifax Harbour, the Straits of Dover, &c., in and out lanes of traffic can be organised which can be maintained with ease in fogs. The Echo methods to which reference has been made can be used for founding, for locating icebergs, surface vessels and rock-bound coasts in a fog as well as for locating submarines.

Helium which was originally produced as a filling for airships can be utilised for the production of illuminating agents and for providing a means of investigating the fundamental properties of matter at the lowest temperatures attainable by man. Developments in internal-combustion engines, in electric drive, and in the fuel values of new materials which were to be corporated in the Navy, will be of enormous value to the mercantile marine in the future.

Advances made in wireless telegraphy and telephony and in secret signalling by specific types of radiation for war purposes, will also prove of great service under peace conditions by providing us with novel, efficient, and less costly methods of communication.

Proposed Scientific Establishments for the Future.

With a view to developing and extending the scientific results which were obtained under stress of war, the Admiralty has recently put forward proposals for the permanent establishment of a Department of Research and Experiment within the Navy.

Plans have been formulated for the erection of a Centrals Research Institution for the investigation of first principles and for carrying on researches of a fundamental and pioneer character. Steps have already been taken to organise a sea experimental station and to provide buildings and equipment for an engineerng laboratory, a wireless and signal school, and a torpedo and mining school in place of the "Vernon." It is believed that these institutions will prove of great value in developing not only means of increasing the efficiency of the Navy, but in providing aids to navigation for our mercantile marine.

The initial expenditure for buildings and equipment will be large, but it seems evident that an ample financial return will in a short time be obtained for the nation from profits accruing from a lowering of the rates of insurance

and from a reduction in the cost of transportation. If we could by the use of such aids to navigation as have been referred to above prevent two or three wrecks per year, or lower the time of passage between Great Britain and Canada on the average by one day per voyage per ship through the fog-covered areas in the neighbourhood of Newfoundland, sufficient funds would be saved in a year or two to cover the whole cost of the expenditure on scientific and experimental establishments and on the prosecution of the researches and investigations foreshadowed.

THE LIMITS OF THERMAL EFFICIENCY IN DIESEL AND OTHER INTERNAL COMBUSTION ENGINES.*

By Sir DUGALD CLERK, K.B.E., D.Sc., F.R.S., M.Inst.C.E.

(*Continued from page* 79.)

In the year 1903 a Committee of the Institution of Civil Engineers was formed to report on the standards of efficiency of internal combustion engines, and that committee conducted an investigation at the works of the National Gas Engine Company, Limited, upon three gas engines having cylinders respectively 5½ in., 9 in., and 14 in. diameter, the brake power ranging from that of the small engine giving 5 horse to the large engine giving over 50 horse. All three engines were adjusted to have the same compression ratio. Its value was 5–5.

One of the objects of the work of the committee was to discover the relationship between the efficiencies calculated by the air cycle and those actually obtained in the working engine.

In the early part of 1907 a paper† was read by me to the Institution of Civil Engineers, on the limits of thermal efficiency of internal combustion motors in which the work of the committee and further work of my own were fully discussed.

In the three engines referred to it was found that the actual indicated power obtained was respectively 0·61, 0·65 and 0·69 of the efficiency value calculated from the air standard. In the small engine obviously the heat losses to the cylinder were greater than in the intermediate and large engine, but the variation between 0·61 and 0·69 was unexpectedly small comparing the respective indicated powers of 6 and 60. Further observations showed that in engines of 14 in. cylinder and above, working under best experimental conditions, the indicated power which could be obtained was 0·7 of that given by the air standard. It was proved that in a 14 in. cylinder gas engine, 35 per cent. of the heat given the engine was transformed into indicated work. As this is only 70 per cent. of what would have been given by an ideal air engine following the same heat cycle, it followed that if the working fluid really had the same properties as air, there was a margin of 30 per cent. for possible improvement, that is, if all heat losses were suppressed the efficiency would rise to 0·50 instead of the figure actually obtained, 0·35.

In order to determine the true margin remaining for improvement it was necessary to know the specific heat of the actual working fluid. This had been determined by several methods, but I was not satisfied with the results of experiments of the earlier investigators. I desired particularly to investigate the heat loss within the engine cylinder during the working stroke, and I desired to determine also the specific heat of the flame within the cylinder during the actual operation of the engine. By means of a new type of indicator diagram shown in Fig. 7,‡ I was able to determine both heat loss and specific heat of flame. From these experiments I calculated the mean apparent specific heat in foot lbs. per cubic foot of working fluid at 0 deg. C. and 760 mm. The results of this determination are given in the table herewith :—

Apparent Specific Heats (Instantaneous) in Foot-pounds per Cubic Foot of Working Fluid at 0 deg. C. and 760 mm. (Clerk).

Temperature.	Specific Heat at Constant Volume.	Temperature.	Specific Heat at Constant Volume.
deg. C.	ft.-lb.	deg. C.	ft.-lb.
0	19·6	800	26·2
100	20·9	900	26·6
200	22·0	1,000	26·8
300	23·0	1,100	27·0
400	23·9	1,200	27·2
500	24·8	1,300	27·3
600	25·2	1,400	27·35
700	25·7	1,500	27·45

Mean Apparent Specific Heats in Foot-pounds per Cubic Foot of Working Fluid at 0 deg. C. and 760 mm. (Clerk).

0–100	20·3	0–900	23·9
0–200	20·9	0–1,000	24·1
0–300	21·4	0–1,100	24·4
0–400	21·9	0–1,200	24·6
0–500	22·4	0–1,300	24·8
0–600	22·8	0–1,400	25·0
0–700	23·2	0–1,500	25·2
0–800	23·6	—	—

Having made these determinations it was possible to calculate a diagram similar to the air standard diagram using, however, the true and varying specific heat of the actual working fluid operating within the cylinders.

As the result of this work it was proved that in this particular 14 in. cylinder engine the indicated thermal efficiency was 0·88 of that which would have been obtained with that particular working fluid had there been no heat losses, that is, in this particular engine the indicated power was 88 per cent. of what it could have been in that particular cycle of operations had all heat losses been successfully suppressed. The real margin for improvement was thus, not 30 per cent., but 12 per cent.

The following table shows the ideal efficiencies of the actual working fluid of this particular engine as compared to the air standard :—

Ideal Thermal Efficiencies with the Real Working Fluid Compressed with the Air Standard Values.

Suction Temp. = 0 deg. C. For Compression Line 1·37.

$\frac{1}{r}$	Maximum Temperature 1,600 deg. C.	Maximum Temperature 1,000 deg. C.	Air Standard.
$\frac{1}{2}$	0·195	0·200	0·246
$\frac{1}{3}$	0·286	0·293	0·360
$\frac{1}{4}$	0·354	0·356	0·430
$\frac{1}{5}$	0·384	0·394	0·480
$\frac{1}{7}$	0·439	0·443	0·550

In this case the thermal efficiency varies with the maximum temperature because of the increase of specific heat of the working fluid as the temperature rises. For a maximum temperature of 1,600 deg. C. the real ideal efficiency is about 20 per cent. less than that shown in accordance with the air standard.

An engine with similar trip gear to that used for this investigation was adopted to determine the effect of turbulence on the rate of ignition. This is important in the working of all internal combustion engines, and it is dealt with in Appendix C.

We are now in a position to consider Mr. Hall Brown's remarks as to special breach of the laws of thermodynamics by slow running gas engines. This particular 14 in. engine tested ran at 260 r.p.m. I suppose Mr. Hall Brown would admit that the large steam turbines are machines of high thermodynamic efficiency. In comparing all steam engines to determine the limit of improvement still open, steam engineers use the well-known Rankine cycle. It is a cycle of operations closely following the actual operations of a steam engine assuming, however, that the whole operations can be performed without heat loss.

I understand from Sir Charles Parsons that the relative efficiency of the large Chicago turbine giving 40,000 h.p. upon one shaft is 76 per cent., that is, this turbine gives 76 per cent. of the work which would be given by a Rankine cycle engine using the same temperature and vacuum. According to this, even the very highly efficient large turbine has a margin of 24 per cent. improvement if all heat losses could be avoided. It is rather remarkable that a small 60 h.p. internal combustion engine should so nearly attain perfection of action as regards heat loss and other matters, that only 12 per cent. remains between theoretical perfection and practical work. It is difficult to see how the thermodynamics of that particular type of engine can be improved.

Mr. Hall Brown falls into error from a very usual belief among some engineers as to the enormous heat loss made in the cylinder, especially of a slow running gas engine. The actual heat losses are much smaller than is generally supposed.

The following mean balance sheet of three separate indicator cards taken by this method for determining heat loss and specific heat shows quite clearly that the heat flow during explosion and expansion is relatively low. The balance sheet is as follows :—

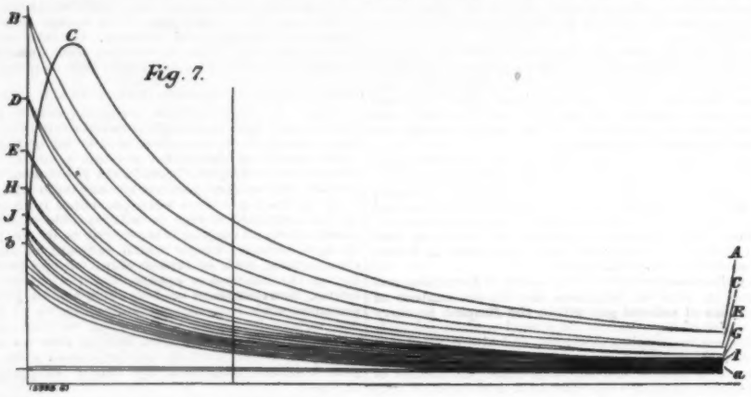


Fig. 7.

FIG. 7. CLERK DIAGRAM FOR DETERMINATION OF APPARENT SPECIFIC HEAT.

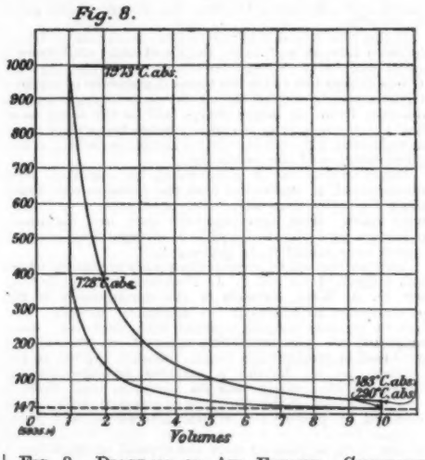


Fig. 8.

FIG. 8. DIAGRAM OF AIR ENGINE. CONSTANT VOLUME TYPE. COMPRESSION RATIO $\frac{1}{r} = \frac{1}{10}$.

Mean Balance Sheet.

Cards Nos. 22, 23 and 24.

	Per cent.
Heat flow during explosion and expansion	16·1
Heat contained in gases at end of expansion	49·3
Indicated work	34·6
	100·0

As here shown, the larger part of the heat loss is that discharged in the exhaust gases from the cylinder of the engine.

From the values it is evident that no great improvement in thermal efficiency would be obtained were the whole 16 per cent. heat loss of explosion and expansion entirely suppressed. Then 16 per cent. at 0·37 indicated efficiency would only give an addition of 5·9 per cent., that is the 37 per cent. would be raised at most to 43 per cent. This total suppression of heat loss is obviously impossible; but considerable improvement may be obtained by raising the compression ratio to 10. Here the air standard efficiency becomes 0·6, and assuming similar heat losses 0·6 × 0·7 = 0·42, that is 42 per cent. indicated thermal efficiency is practicable without reducing the heat loss to the piston and enclosing metal walls. In a multiple cylinder engine the mechanical efficiency may be taken as 90 per cent. so that the greatest probable brake efficiency would be 43 × 0·9 = 38·7 per cent.

From the results of prolonged experience of internal combustion engines during many years it may be taken that for explosion gas engines of the four and two stroke types the extreme practicable compression ratio $\frac{1}{r}$ is $\frac{1}{10}$ and the maximum probable brake thermal efficiency is 39 per cent.

At this value the engine will give in power about 88 per cent. of the maximum possible assuming all explosion and expansion heat losses to be avoided.

The indicator diagram of the air standard engine under these conditions is shown at Fig. 8. It will be seen that the pressure of compression is high, 369 lb. per square inch absolute and the maximum or explosion pressure 997 lb. per square inch absolute. The terminal

* Paper read before the North-East Coast Institution of Engineers and Shipbuilders, 1919.

† "The Limits of Thermal Efficiency in Internal-combustion Motors," By Dugald Clerk. Proc. Inst. C.E., vol. clxix, session 1906–1907. Part iii.

‡ See Appendix B for explanation of this method.

pressure of exhaust is low, under 40 lb. absolute. A small addition to the work area might be made by discharging the gases through an expanding jet and actuating an impulse gas turbine, but not more than 5 per cent. addition to the brake power could be obtained in this way. At the extreme the brake efficiency might be so raised by 2 per cent., it might become 41 per cent. instead of 39 per cent.

Compounding in cylinders has been attempted many times, but the increased heat loss of transfer from high pressure to low-pressure cylinder has rendered the gain in efficiency too small to be worth the additional weight and complication of the engine.

There appears to be only one method open to further increase of heat economy in a practical way, and that is by using regeneration of heat in some form. The utilisation of the waste heat of the water jacket and the heat of the exhaust gases to raise steam has become considerable. About 2·5 lb. of steam per brake horse-power have been obtained from the exhaust gas heat of large gas engines. Many installations of this kind have been at work for about fifteen years back. The steam generated has not been used for producing motive power but for boiling and heating operations in chemical factories. If in such large installations the steam had been used in a high efficiency Parsons steam turbine requiring 10 lb. of steam per brake horse-power, then 25 per cent. could have been added by steam expansion to the brake power obtained by internal combustion.

In an engine giving 39 per cent. brake thermal efficiency there remains 61 per cent. of the original heat of the engine part of which could be used to raise steam. Of these 61 heat units, 4 are partly lost by engine friction and about 10 by radiation, so that the heat remaining for use is 61 — 14 = 57, that is 57 per cent. of the original heat. In a boiler of 80 per cent. efficiency this would enable 45·6 per cent. of the original heat of the gas to be delivered to a steam engine. Used in a Parsons' steam turbine of 18 per cent. thermal efficiency, brake power to steam heat, would give an addition of $57 \times 0{\cdot}18 = 10{\cdot}2$, that is, with the brake efficiency of one regenerative gas and steam engine would rise from 39 per cent. to slightly over 49 per cent. It may be taken then that high compression engines in large units with steam turbine addition might raise the brake efficiency to 49 per cent.

No such efficiencies have yet been obtained, although many attempts have been made to utilise waste heat in this way. As early as 1850 Du Trembley, a French engineer, attempted to increase the economy of a marine steam engine by using the waste heat from the steam cylinder exhaust to evaporate ether in a separate boiler and so get a further supply of vapour under pressure to actuate an additional piston in a cylinder. An account of this engine is given in Rankine's* book on "The Steam Engine."

An account of a combined internal-combustion and steam engine was given by me, written in 1885, in a book on "The Gas Engine," first published by Longman and Co. in 1886. There I state :—

"Messrs. Simon, of Nottingham, introduced a Brayton engine to England in a slightly altered form as a gas engine. In addition to the ordinary arrangement of the engine, they attempted to gain increased economy by causing the waste heat passing into the water jacket and the heat of the exhaust gases to be utilised in raising steam. They would undoubtedly have increased the economy of the engine in this manner had they not turned the steam so raised into the motor cylinder along with the flame."

And further I say :—

"With a suitable arrangement using steam in a separate cylinder, doubtless 6 per cent. might be added to the indicated efficiency of the engine, but it is very questionable whether the increased complexity does not entirely destroy any advantage gained. It certainly does so in small engines, but when very large engines come to be constructed the complexity will not be so great, and it would be worth while to use the waste heat in steam raising."

The Simon engine was exhibited in operation at the Royal Agricultural Show in Bristol in 1878.

This same question of regeneration by steam was discussed by me in the new edition of my book "The Gas, Petrol and Oil Engine," published in 1913, the chapter being written by me in 1912.

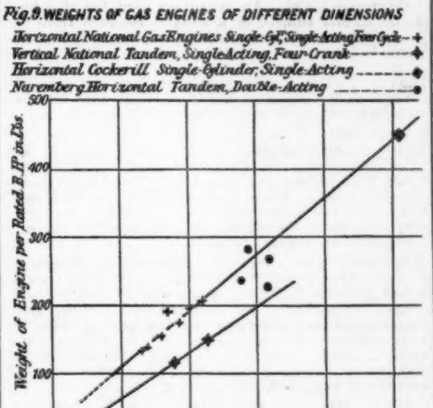
There I stated that the brake thermal efficiency of a combined gas and steam engine (steam turbine) would be about 43 per cent.

Of late years Mr. Still and Captain Ackland have taken up this subject, and they have built a number of explosion and constant-pressure gas, petrol and heavy oil engines, from which very interesting results have been obtained. They have read an interesting paper upon the subject at the Royal Society of Arts, and the best result claimed by them was obtained with a two-stroke engine of the opposed piston type working on the constant pressure principle Diesel modification, combustion space between the pistons and steam on the other side of each piston. This engine gave a brake thermal efficiency (combined) of 41 per cent. The engine cylinder was 13·5 in. diameter the combined stroke 22 in., and it comprised two pistons, two piston rods with packing glands, two crossheads, three connecting rods and three cranks. The pistons overrun exhaust and air or charge inlet in the same way as the old Oechelhauser gas engine and the later Junker modification. These engines operate on a modified Clerk two-stroke cycle. The work necessary to operate the auxiliaries, air scavenging and supply, &c., is not allowed for in the efficiency figure of 41 per cent., and it could not well require less than 10 per cent. of the brake power, that is 4 per cent. deduction. And 41 — 4 = 37 per cent. The addition of steam in this case has not increased the net brake efficiency to as high a value as could have been obtained without steam addition by high compression as already discussed. Indeed, in Mr. Still's paper the highest Diesel brake efficiency as determined by Mathot is given as 36 per cent. From this it would appear that even Acland's and Still's experiments do not prove any material advantage to have been obtained in the Still engine. There is considerable advantage to be gained from steam regeneration as I have already pointed out, but it appears necessary to bring in the Parsons' high efficiency separate turbine in order to obtain it.

It only remains to discuss shortly the efficiencies of the Diesel and the petrol engines.

Mr. Ricardo in his excellent paper, to which I have already referred, has fully discussed the conditions of petrol engine efficiency, and because of the low ignition temperature of petrol vapour and air he limits the practicable compression ratio to $\frac{1}{5}$ with an air standard efficiency of 47·5 per cent. Multiplying by the factor 0·7 which gives the actual results from air cycle to the practical engine, we get $47{\cdot}5 \times 0{\cdot}7 = 33{\cdot}2$ per cent. indicated thermal efficiency, and this in a multiple cylinder engine with a mechanical efficiency of 90 per cent. will give a brake thermal efficiency of nearly 29·9 per cent. This, however, is rarely attained in petrol engines; in such engines 25 per cent. may be considered a good working efficiency.

Fig. 9. WEIGHTS OF GAS ENGINES OF DIFFERENT DIMENSIONS



The greater the waste heat, the better the proportional improvement to be expected from the additional steam, so that considerable improvement could be so made in petrol engines. But at present, when, for aircraft, weight per B.H.P. is the controlling factor, the complications and additions could not be allowed. The objection also applies to motor-car engines, wherein it would not be advantageous in practice to increase complexity and weight by the addition of steam-generating apparatus. Petrol engines need not be further considered from this point of view. Compression ratios, however, may be increased by adding cold exhaust gases to the mixture by super compression or without it, and by this, higher compressions and efficiencies are quite possible.

We now pass to the Diesel type. It has been considered already to some extent. Undoubtedly, much further study and experiment are desirable. Little study has been given to the Diesel indicator diagram and less to the conditions of heat flow and exhaust loss. These should be very fully determined. Optical indicators should be used and zigzag diagrams should be taken to determine specific heat and heat loss in the cylinder.

Diesel efficiency is undoubtedly high, but by no means higher than can be obtained from constant volume or explosion gas engines when designed and built for high-explosion pressure. The great problem in all Diesel engines is that of the formation and projection of all spray; the spraying at present dominates the efficiency values obtainable.

The air standard efficiency shown on the Diesel type of diagram, Fig. 5, is 0·56. Assuming heat losses similar to those of the explosion gas engine, the indicated thermal efficiency to be expected in the working engine would be $0{\cdot}56 \times 0{\cdot}7 = 39{\cdot}2$, and assuming as before a mechanical efficiency of 90 per cent. in a multiple cylinder engine the brake thermal efficiency would be $39{\cdot}2 \times {\cdot}9 = 35{\cdot}3$ per cent. With a compression ratio of 15, however, which is quite practicable in a Diesel engine, the air standard efficiency would be 0·62 and the indicated efficiency using the factor 0·7 would be 43·4 per cent. given at 90 per cent. M.E. a brake thermal efficiency of 39 per cent. It is probable that in the case of Diesel engines the conversion factor will prove to be higher than 0·7 as the conditions of heat-flow from fluid to cylinder are more favourable than in the explosion engine. Accordingly, it is to be expected that a combined high compression and regenerative steam cycle will give brake efficiencies approximating to 50 per cent. as in the case of the explosion engine.

Mr. Still's combined brake efficiency of 41 per cent. can undoubtedly be improved upon by the use of the steam turbine as the steam part of the combination.

It is of considerable importance to study the Diesel heavy oil engine much more closely than has yet been attempted with the view of getting maximum brake efficiencies. There are many purposes for which the Diesel is indispensable. The cost and scarcity of oil, however, will, in the end, limit its expansion compared with gas engines using anthracite or bituminous coal.

Much greater attention should be paid to large gas producers using anthracite and steam coal in order to apply the more plentiful fuel coal to all high-power engines whether used on land or sea. The efficiency of these gas producers could be raised to about 95 per cent., and so the high efficiency of the gas engine, gas heat to B.H.P., would be more fully realised than at present when the efficiency is from 80 to 85 per cent.

APPENDIX A.

ON VARIATION OF ENGINE WEIGHT WITH INCREASING DIMENSIONS.

Extract from *The Gas, Petrol and Oil Engine*, by D. Clerk and G. A. Burls, Vol. II.

COMPARISON OF THE DIFFERENT TYPES OF FOUR-CYCLE ENGINES.

It will be seen from the foregoing account of the development of these engines, that the smaller engines up to 200–250 B.H.P. are built preferably of the single-acting open-cylinder type as single horizontal cylinders, while for large engines the favourite type is the horizontal single-crank tandem double-acting engine, in which the two cylinders between them give the crank two impulses per revolution. These tandem engines are built from 22 in. to 52 in. cylinder diameter, giving from 400 B.H.P. to 3,000 B.H.P. to one crank.

Vertical engines are also considerably used, especially in England, and for power up to 2,000 B.H.P. per four-crank unit in the tandem single-acting type they present considerable advantages which make them formidable competitors with the tandem horizontal double-acting engine. A certain number of single-acting tandem horizontal engines have also won a position in the market, but on the whole, opinion tends to look at the others more favourably.

A comparison of the weights per B.H.P. of different types of engines is useful, as showing the reasons for preferring the multiple and double-acting cylinders for large gas engines. But, first, it is to be remembered that in all engines the weight per unit of power developed increases with increasing dimensions. The following table shows the total weight and the weight per B.H.P. developed for various types of engines. The first part of the table gives particulars of National gas engines of the horizontal type, each engine having one cylinder of the open trunk single-acting type. The engines are those of the latest design as now built by the company.

Particulars of the large single-cylinder Cockerill engine are also given, and also two examples of the favourite Continental horizontal tandem double-acting type, and lastly, two examples of the new National tandem single-acting vertical engines.

SOME PARTICULARS OF GAS ENGINES OF DIFFERENT DIMENSIONS AND TYPES.

Horizontal National Gas Engines, Single-cylinder, Single-acting, Four-cycle.

Rated B.H.P. with coal Gas.	Diameter and Stroke.	Stroke bore ratio.	Revolutions per min.	Piston speed ft. per min.	Wt. of engine tons.	Wt. per rated B.H.P.
	ins.					lbs.
57	13×20	1·538	230	408	3·33	131·0
68	14×21	1·500	230	537	4·08	134·5
85	16×22	1·375	210	560	5·82	153·5
105	17×26	1·530	190	530	9·08	193·5
125	18·5×28	1·515	180	555	9·48	170·3
150	20×31	1·550	170	567	13·20	197·7
185	22×34	1·545	160	587	17·05	206·5

Horizontal Cockerill Single Cylinder, Single-acting, Four-cycle.

Rated B.H.P. with blast furnace gas.	Diameter and stroke.	Stroke bore ratio.	Revolutions per min.	Piston speed ft. per min.	Wt. of engine tons.	Wt. per rated B.H.P.
	ins.					lbs.
800	51½×55	1·07	75	470	160	448

Horizontol Continental Tandem, Double-acting, Four-cycle.

800	28×34	1·21	130	736	85	238
1,000	32×40	1·25	110	733	120	269

Vertical National Gas Engines, Tandem, Single-acting, Four-cycle.

750	18×18	1·00	300	900	39·0	116·5
1,250	26×24	1·00	200	800	83·5	149·0

It will be observed that while the horizontal National gas engine of 57 B.H.P. with a 12-in. diameter cylinder gives 1 B.H.P. for 131 lbs., the 185 B.H.P. requires 206·5 lbs.

The large Cockerill horizontal engine requires 448 lb. weight for each B.H.P. The tandem double-acting engines require respectively 238 lb. and 269 lb. per B.H.P., and the two National vertical single-acting tandem 116·5 lb. and 149 lb. per B.H.P., respectively.

For each separate type there is an increase of weight

* Rankine, "The Steam Engine." Page 444, 12th edition, published in 1888, Griffin and Co.

per B.H.P. with increasing power or cylinder diameter.

This is more clearly shown at Fig. 9, page 131, where the weights per B.H.P. are plotted against cylinder diameter.

In the open trunk single-acting horizontal engines the rate of increase or weight with increasing cylinder diameter appears to be linear. Six out of the seven National engines fall closely round a straight line drawn from the point indicating the weight of the large open trunk Cookerill engine. The one weight which is off the line is that of the 17 in. cylinder, in which the frame was purposely made heavy in order to save patterns by using it also for the next size of 18·5-in. cylinder. This line then shows that while a 9-in. cylinder would involve about 100 lb. per B.H.P., a 56-in. cylinder would require about 500 lb. per B.H.P.

The vertical National engines show that a 9-in. cylinder would require less than 60 lb., and a 30-in. cylinder under 200 lb., per B.H.P.; a 30-in. cylinder of the open trunk type would require just under 280 lb. per B.H.P

Fig. 10.

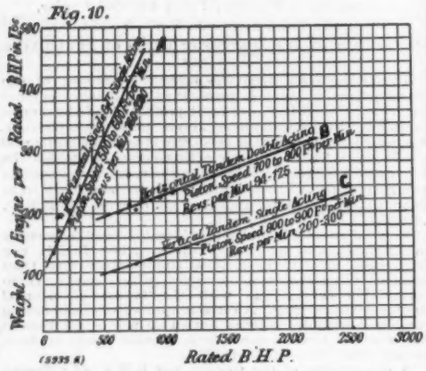


FIG. 10.—COMPARISON OF WEIGHTS PER RATED B.H.P. OF DIFFERENT TYPES OF GAS ENGINE FOR INCREASING POWERS.

The weights for the Continental tandem double-acting engines come between the upper and lower lines.

The following table gives the weights per B.H.P. of nine Continental engines of the horizontal tandem double-acting type, from which it will be seen that there is a fairly regular increase of weight per B.H.P. with increasing power.

WEIGHTS OF LARGE CONTINENTAL GAS ENGINES OF THE TANDEM, DOUBLE-ACTING, FOUR-CYCLE TYPE.

Brake H.P.	Net weight of engine with fittings but without flywheel.	Net weight of flywheel.	Weight of engine per B.H.P.	Weight of flywheel per B.H.P.
	Tons.	Tons.	Lbs.	Lbs.
2,000	266·5	—	298·5	—
1,500	162·3	34·5	242·5	51·3
1,000	109·3	—	231·0	—
1,000	120·0	—	269·0	—
950	95·1	25·0	224·0	58·8
800	85·0	—	238·0	—
750	68·5	17·7	204·5	52·6
700	81·7	15·7	261·0	50·2
630	66·5	—	237·0	—

Fig. 10 shows the weight of the engine per B.H.P. plotted against rated B.H.P. for the engines of which some particulars are given in the two tables.

The horizontal single-acting engine has obviously the most rapid rate of increase when compared either with the tandem double-acting or the vertical tandem single-acting.

On line A a weight of 300 lb. per B.H.P. only gives an engine of about 470 B.H.P., while on B a power of 2,050 B.H.P. is obtained for the same weight; this same power of 2,050 B.H.P., however, can be obtained on line C by a weight of 200 lb. per B.H.P.

The diagram very clearly shows the reasons of the success of the Continental horizontal tandem and also the reasons which induce the English designers of the Westinghouse and National tandem vertical engines to produce multiple cylinder engines for large powers.

(To be continued.)

HYDRAULIC POWER IN FRANCE.—We read in the *Revue Scientifique* that since the commencement of the war remarkable progress has been made in France in turning to account the water power available in the country. From 1916 to 1918 there were put down installations for a total of 450,000 h.p.; plant is being installed for 175,000 h.p., to be working in the course of the present year; whilst further plant for a total of 225,000 h.p. is being built to be ready in 1920–21. The total is 850,000 h.p. In 1913, the water power utilised yielded 750,000 h.p. In 1921, therefore, the water power installations in France will yield 1,600,000 h.p. This latter figure is only one-fifth of the power which can be obtained hydraulically throughout the country according to present estimates.

CATALOGUES.

Asbestos.—An instructive essay on the uses, nature and origin of asbestos, in booklet form, has been received from Messrs. Turner Brothers Asbestos Company, Limited, Rochdale.

Drawing Supplies.—A priced list of drawing instruments, slide rules and black and coloured inks and pencils comes from Mr. Albert E. Mallandain, 51, Cheapside, E.C. The information is precise and sufficient.

Street Lighting.—An interesting essay on the diffusion of light in public thoroughfares fills the main part of a pamphlet issued by Holophane, Limited, 12, Carteret-street, S.W.1. The Holophane lanterns and refractors are described, and the matter throughout is accompanied by useful diagrams.

Deflectometer.—An instrument for measuring the deflection of bridges, floors, pillars, &c., especially those of ferro-concrete, is described in some circulars received from the maker, Mr. Gustav Griot, Zurich, Switzerland. A wire is attached to the instrument and the underside of a floor, and the deflection indicated on a dial in inches or millimetres.

Thermometers.—A wide range of glass thermometers for various industries is shown in a catalogue from the Cambridge Scientific Instrument Company, Limited, Cambridge. These are specially suitable for steam plant, chemical works, brewing, sugar boiling, refrigerating, oil tempering and molten metal. Another catalogue deals with electrical distance thermometers, both indicating and recording.

Expansion Joint.—An expansion joint for pipe lines is the special subject of a booklet received from the Ross Heater and Manufacturing Company, Buffalo, New York, U.S.A., who make these joints in a full range of sizes for pipes from 1¼ in. diameter to 48 in. diameter. The travel is 4 in. or 8 in., and all pressures up to 1,000 lb. per square inch are provided for. The joint is designed on substantial and free working lines.

Tram Cars.—Several types of electric tram cars are described and illustrated in a catalogue issued by the J. G. Brill Company, Philadelphia, and 110, Cannon-street, E.C. There is a neat single-deck car, on which one man acts as driver and conductor, two-deck cars, and a very low-built centre entrance car. The control gear is specially worked out to give easy operation and automatic safeguards against accident.

Minerals.—The Northern Exploration Company, Limited, 62, London Wall, E.C.2, has issued a booklet to call attention to British commercial interests in Spitzbergen Archipelago. It is stated that there are great quantities of high-grade iron ore, coal, pyrites, asbestos, molybdenite, graphite, lead and gold, as well as many splendid marbles and other materials. Some very fine illustrations appear, and the position relative to other countries is explained.

Electric Hoists.—A catalogue from the Electric Hoist Manufacturers' Association, 9, West Fortieth-street, New York, illustrates the American genius for combined action in trade. It represents 11 large American firms engaged in making hoists and special parts of hoists, and offers buyers an unbiassed choice of all their productions and expert advice on all or any of them. About 20 various kinds of hoists specially suitable to various industries are illustrated and briefly described.

Steel Material.—A series of circulars, each dealing with a special steel for automobile and aircraft engine work, comes from Messrs. Vickers, Limited, River Don Works, Sheffield. These include mild and nickel steels for case hardening, medium and high-tensile carbon steels, nickel and nickel-chromium steels, also a self-hardening nickel chrome steel. Each circular, there are thirteen, explains the use, composition and heat treatment, states strength test and analysis figures. These should prove very useful to engineers.

Engines.—The Parsons Motor Company, Limited, Southampton, send a book illustrating the various adaptations of their small engines to land work, both stationary and portable. The engines are of seven h.p. and multiples of seven generally, up to 42 h.p., but in some cases as high as 90 h.p. They are incorporated in units for generating electric current, welding, pumping, air compressing, small locomotives, various agricultural machines, stone crushing machines and a compact unit at various powers giving a pulley drive for factory, workshop or other similar purpose. Some useful layout drawings are also given.

Baling Presses.—Some examples of boxed and open baling and packing presses are shown in a catalogue from Messrs. Hollings and Guest, Limited, Thimble Mill-lane, Birmingham. These are based on the firm's hydraulic machinery, and consist in adding strong and convenient frame work to suit the needs of various manufacturers, packers and merchants. Although rough, strong structures, they show evidence of some ingenuity in economising space and providing easy approach for workmen. A new catalogue of pumping machinery comes from the same firm, showing hand-lever, belt and electric motor drives with toothed or chain-wheel reduction gear, specially made for press work.

Friction Fabric.—An important manufacturing industry, and on a large scale, has been built up by the Herbert, Frood Company, Limited, Chapel-en-le-Frith, Derbyshire, makers of "Ferodo." Practically a single material is made, but the company have closely followed up the uses to which this material is put by engineers, and have supplied it in the form required for every one of its many applications. The company's work and methods are an excellent example of how industry should be built up and maintained. Eight leaves pinned together have reached us explaining some of the adaptations of Ferodo in simple text and clear illustrations. They deal with an item of material which the engineer cannot well manipulate with his own tools or machines, and he is glad to get it in exact form ready for use.

Electric Winders.—Evidence that electrical machinery is making progress in mining for winding and haulage work is given in a publication issued by the British Westinghouse Electric and Manufacturing Company, Limited, Trafford Park, Manchester. It contains about 50 finely-printed illustrations of winding motors and drums with all necessary gear—as an example, an alternating-current 730 1,500 h.p., direct-coupled motor for winding a net unbalanced load of 6,720 lb. on a 12 ft. diameter drum, at a speed of 1,900 ft. per minute in a shaft 1,080 ft. deep at Wallsend-on-Tyne. A great variety of installations supplied by the company are shown. The company also send specimen copies of their *Club News and Gazette*, monthly papers containing news of special interest to the employees, and both excellent examples of this class of literature.

Small Locomotives.—The small locomotive has been extremely well worked out by the Motor Rail and Tram Car Company, Limited, Simplex Works, Bedford. The engine will haul up to 100 tons on the level rails, at speeds from 1 to 12 miles per hour. Two smaller sizes are also shown. All four wheels are driven. The controls, look-out, braking, sanding and all necessary minor facilities are carefully provided for, and the driving made easy and comfortable. The engine fuel is petrol or paraffin, the latter giving 20 per cent. less power. Rail gauges from 18 in. to the standard 56½ in. are built to. For shunting and yard and shop haulage these engines are proving very useful and economical. They are always ready for use, and as they are seldom in constant use, the saving in fuel cost is considerable as compared with small steam engines. The catalogue contains several interesting pictures of the working of these engines on the battlefields.

Building Blocks.—A machine for making concrete building blocks, slabs, flue blocks, &c., has been very thoroughly worked out by Messrs. Winget, Limited, Warwick, and 25, Victoria-street, S.W.1. The concrete is tipped into a moulding box and tamped or hammered down; the box is then stripped from the formed block by a pull on a lever and the block is left clear on a plate for carrying away. The blocks are 32 in. by 16 in. by 9 in. solid as a maximum, and a variety of sizes are provided for by dividing the maximum space. Rough, smooth and pattern faces, and various cores, are also provided for. All parts of the machine are standard, and any part can be replaced at once. The machine forms part of a system of making blocks in or near the building site, and may be operated to full advantage by three or four men or women. The system should receive special attention from those interested in building small houses. Another catalogue describes a concrete mixing machine, mounted, with small engine, on a truck.

Oil Engines.—A series of tests, conducted by Professor F. W. Burstall, of Birmingham, on the cold starting oil engines made by Messrs. Crossley Brothers, Limited, Openshaw, Manchester, are recorded in a 12-page quarto booklet. The engine tested was 18¼ in. diameter cylinder and 28-in. stroke; speed, 180 r.p.m.; fuel, normally, residual or tar oils. Tests were made with three fuels:—(1) Refined kerosene, (2) residual petroleum, and (3) tar oil with small pilot injection of refined oil (about 3 per cent. of the total charged). The results, which are fully tabulated, show a consumption of fuel (2) per brake horse-power per hour of 0·425 lb. at 125 brake horse-power. The normal rated load of the engine is 117 brake horse-power. The consumption is very little more *pro rata* at 21 per cent. overload, and remains steady *pro rata* down to nearly half load. The results are to the credit of the engine as proof that it will carry a widely varying load at a fuel consumption which is substantially unvarying per horse-power of work done. That is what the factory owner or other user is commercially interested in. This type of engine is started without preheating, and is self-firing (or ignites by compression). The report is worth careful attention. Its value is increased by a concise fair-minded historical introduction, which gives due credit to Beau de Rochas, Priestman, Stuart Ackroyd and Diesel for their ideas and work in developing the heavy-oil engine.

EXPORT REGULATIONS.—The Export Licence Department announces that the blockade of Germany having been raised an open general licence has been issued permitting the export of goods on list "C" to all parts of Germany without the necessity of obtaining individual export licences or observing any special formalities. Goods exported via Holland need no longer be consigned to the Standard Bank of South Africa, Rotterdam. In the case of Holland and Switzerland, consignment to the Netherlands Oversea Trust and Société Suisse de Surveillance Economique respectively is no longer necessary. A further open general licence authorising the export of list "C" goods to Finland was issued recently, but although British export licences will no longer be necessary, exporters are advised to instruct their consignees in Finland to obtain any import licences which may be required by the Finnish authorities. List "C" still applies to Poland, North Russia, Esthonia, Lithuania and Lettland (Latvia); but no licences are as yet being granted for Lithuania or Lettland except for foodstuffs. Further particulars may be obtained from the Department of Commercial Intelligence, 73, Basinghall-street, E.C.2.